SILICON CHIP

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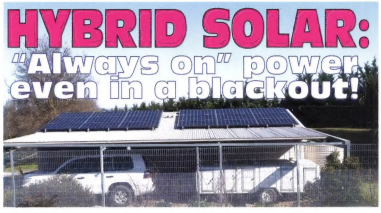

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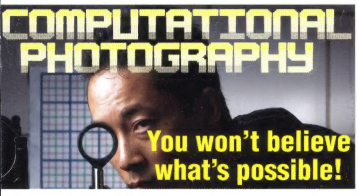

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- PCB: 38 x 35mm

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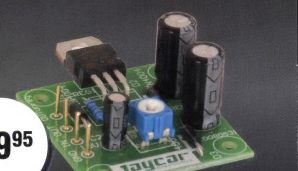

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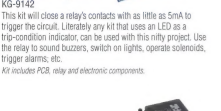
- PCB: 72 x 30mm

Kit includes all PCB and components for board (transformer not included).



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PCB: 34 x 18.5mm.

Kit includes double sided, solder-masked and screen-printed PCB with SMDs pre-soldered, voltage setting diodes and resistors, and components.

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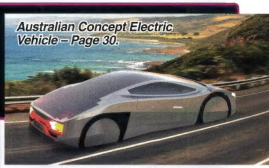

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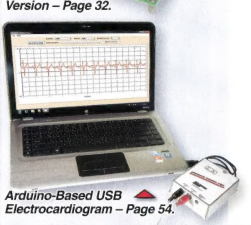

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Publisher's Letter

Hybrid solar systems can work well

This month, we have a report on a hybrid solar system that I recently visited, just outside the NSW country town of Yass, thanks to an invitation by the owner, Geoff Woodman. It answers a lot of questions that readers may have about hybrid systems, especially if they are mulling the idea of going "off-grid". I must admit that I have not been enthusiastic about grid-tied solar systems and particularly not the generous subsidies that were originally available. While they were a boon to anyone making an early installation, they were clearly unfair to all other electricity consumers and taxpayers in general, the ones who had to foot the bill for those generous subsidies.

But now solar panel installations are being made on a much more sound economic basis. Many commercial and industrial buildings and even some shopping centres are being fitted with quite large installations and with grid feed-in not being part of the equation. Instead, the idea is that all the power (OK, energy for those who are pedantic about it) being generated on the roof will be used on the premises. A good example of this is an installation right next door to our own premises in Brookvale, Sydney. Rated at 37kW, it will mainly run the ovens and lighting in a crash repair business. Makes sense, doesn't it?

Mind you, if we have a blackout in the area, that business will be blacked out too, as this is not a hybrid installation; no batteries are involved.

The installation at Yass is a full hybrid system, with a large battery bank and only limited grid feed-in allowed. What does get fed in gets a low feed-in tariff of $0.06/kWh. The aim of this system is to be largely self-sufficient, with enough solar panel and battery capacity to support the household for 24 hours or more, with or without the electricity grid. In fact, since the main electrical load is a reverse-cycle air-conditioner, if this was only used sparingly, the installation could probably run indefinitely with the electricity grid being out of operation.

But the installation is tied to the grid and that means that the owner has the assurance that he should have electricity all the time, even allowing for occasional power outages and during days or weeks of very overcast or wet weather. He even has the option of being able to charge the battery bank at night, using the off-peak tariff.

Mind you, he still has to pay the daily service charge and as most people know, these charges have increased at a far greater rate than the increase in power tariffs. In my opinion, the energy retailers are being most unfair with this practice. You can argue that their own cost of electricity is going up but there is little justification for the very large increases in daily service charges that have been made over the last five years or so. To give an example, the daily service charge for our own premises is now $1.75. That really rankles with me.

It is those large daily service charges which are partly driving some people to consider going "off-grid". To me, that is still not an economic proposition, particularly for those living in cities and towns. And you are definitely "on your own" if your solar system develops a fault and a major component like the inverter needs service or replacement. Inverters are the weak link in these systems and they often fail just after the warranty runs out.

Yes, systems like Tesla's Powerwall may change the financial equations but we will have to wait and see. It would seem that if the electricity retailers saw a general trend with their customers going "off-grid", they would quickly modify their approach with their tariffs and daily service charges, in order to retain as many customers as possible.

Leo Simpson

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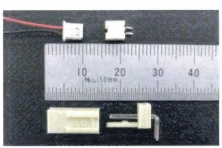
SMD circuits cannot be easily bread-boarded

I read the Publisher's Letter in the September 2015 issue on the challenges and opportunities offered by the use of SMD components. I have constructed a number of projects using SMDs and agree with his conclusions. However, I can add a few more "challenges" to those mentioned that affect those of us who like to develop their own "one-off" designs.

When developing and testing a project where I want to use SMD ICs, I have to either buy both the SMD and its through-hole version so that it can be "breadboarded" or, if the device is only available as an SMD, make up a through-hole adapter for it. Using a development board, such as those for Arduino, rather than being able to choose from the huge range of CPUs available, perhaps better suited to the job at hand, means that one is committed to that CPU only.

One of the most obvious opportunities of SMDs is the capacity to produce small compact devices that operate at low currents and voltages. However, it seems pointless to bother to build a board with SMDs that then needs a



connector to a screen, keyboard, battery or even to a LED where the only connector available often occupies more board area than all the other circuitry and components combined. I find that when scrapping appliances, the tiny PK screws and board header sockets and plugs are the components most worth salvaging.

Where then, can I source the ancillary micro-miniature SMD or through-hole board-to-wire connectors that one sees inside nearly every commercially manufactured item (eg, inside an old cable PC serial mouse, as in the accompanying photo of two 2-pin connectors)?

Incidentally, on the subject of component suppliers, many of those connected with the manufacture of automotive parts are facing tough times ahead when Holden ceases manufacture here in South Australia and many will fail. A few with markets other than the car-makers are adopting a brighter outlook. These are the few who disregarded the economic rationalist dogma preached by economists and business advisers not so long ago, where businesses were admonished to "stick to your core business and out-source everything else".

Just goes to show that in business, like anything else, you should develop and trust your own judgement.

Peter Lawson,
Henley Beach, SA.

Too many products produce EMI

I do think that the comment concerning EMI (Publisher's Letter, August 2015) understates the situation across the board. I spent a lot of time in quality control and it was well recognised as far back as the 1970s that one of the most important issues was

Electromagnetic interference from LED drivers

I have personally experienced the effect of EMI generated from LED light drivers and confirm that these lights can indeed wipe out AM radio reception, as noted in the Publisher's Letter, August 2015.

A year or so ago, I replaced the incandescent globe in my workshop bench light with a LED light. However, I soon discovered that I was unable to listen to the cricket on ABC AM radio due to the EMI generated by the LED driver.

The January 2014 party strobe article by Ross Tester showed me that LED lights can be driven using DC rectified from a suitable mains transformer and a series current limiting resistor. I therefore installed a small mains transformer, rectifier, etc, along with a modified MR16 downlight holder, into my bench light. Finally, I removed the inverter circuit and fitted an appropriate heatsink to the MR16 LED before installing it into the lamp holder.

This bench LED light has now been operating for over 12 months and is working fine.

A few months ago, my son questioned me about the lights he should install in his sound recording studio that he was building in his backyard shed. This resulted in me building four mains-powered linear DC supplies that can each drive up to three 8W MR16 LEDs via separate current limiting resistors.

The MR16 LEDs used were purchased from Altronics (PN X2292) and were chosen because the inverter circuit can be easily removed in a few minutes. Apart from the low power consumption of these modified LED lights, they have the added benefit that there is no EMI to get into recording equipment.

I accept that the linear power supplies I used, together with the limiting resistors, are much less efficient then the electronic inverters normally fitted to LED lights (possibly 60% versus 90%). However, the overall power consumption will be much lower then standard MR16 halogen lights for the same light output.

Stan Woithe,
Fulham Gardens, SA.

to be able to guarantee the quality of the materials etc that made the product in order to (in many cases) eliminate variables, to ensure product quality. This approach has now gone out the window and you can import any form of noncompliant and often patent-infringing rubbish you like with impunity. America is having the same issues.

So far, I have a fax, set-top box (also rubbish quality), one computer power supply, compact fluorescent lights, refrigerator, split-system air-conditioner, a DIN rail timer, a cordless drill (that also produces ozone) and the usual sprinkling of plug-in switchmode supplies. This is aside from some of the underrated parts and bad wiring, plus inferior components.

Clearly our governments could save millions by getting rid of several statutory bodies that are allegedly enforcing regulations.

Marc Chick,
Wangaratta, Vic.

SMDs do not give that same excitement when building a project

In the Publisher's Letter of the September 2015 issue, he extols the virtues of SMDs.

Firstly, the hobbyist is to a great extent reliant on components designed for industry. We tend to use what is available and affordable. For that reason, a move to SMDs will likely be inevitable as components with pigtails are replaced and existing stocks are consumed.

SMDs are favoured by industry because their reduced size means smaller packages and SMDs lend themselves to automated construction. For the hobbyist though, miniaturisation is rarely an attraction. Ease of construction is far more important.

My first projects in the 1960s (ABC-3 etc) were built on a chassis, had strips of solder lugs and could give you a nasty jolt if you touched the wrong terminal! I remember having to save a week's pocket money to buy a single transistor. Yes, we can make some very complex things these days but nothing can rival the excitement of powering up a valve radio for the first time.

Soldering an SMD onto a board made in a factory just isn't the same.

Rob Allan,
Echuca, Vic.

Magnet sensor in finger has a sound technical basis

Having read the story on Biohacking in the August 2015 issue, I do wonder from where Dr Maddison got his qualifications. His suggestion that a magnet implanted somewhere on a human body could detect electromagnet radiation should not be believed. Much of what he writes is highly questionable, from highly questionable sources.

Keith Ross,
via email.

Comment: Dr Maddison is a regular contributor to Silicon Chip *magazine*

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Mailbag: continued

Handy hint for transformer winding

I read Peter Walsham's interesting letter in the June 2015 issue of SILICON CHIP, concerning his hypothesis on the cause of transformer failures. It prompted me to offer this suggestion for those into transformer rewinding.

To avoid potential problems and to provide superior insulation resistance, try using measured strips cut from plain, clear oven-roasting bags although for obvious reasons, DO NOT use the aluminised variety!

This material is usually a polyester film possessing excellent dielectric properties and is highly heat resistant (obviously!). Because it is impermeable it is necessary to stop the insulating varnish as you complete each winding layer. This is not a disadvantage as it may be argued that even with paper inter-layers, any varnish may not fully penetrate to the deeper inner layers. This is another factor, by the way, that may contribute to early transformer failures.

On another subject, I've deliberately held back from comment in the past but now feel compelled to "let loose". When the Publisher ventilates a subject in his leading-page letter he unwittingly seats himself upon a swaying, narrow duck-board precariously suspended over a vat of stinking you-know-what with a queue of eager punters lined up for their turn to throw; the guy at the front – toe on the line – his best aiming eye focussed laser-like on the trigger-paddle while slow-juggling a hard rubber ball in his pitching hand . . .

I am sick of hearing from these petty, thin-skinned types who don't seem to grasp that the subject chosen is entirely the Publisher's prerogative. If you don't like it, just turn the page!

Andre Rousseau,
Pakapura, NZ.

A conventional loudspeaker is an example of an AC magnetic field interacting with a magnet to create movement. In the case of an implanted magnet, the story described those sensations as reported by users which is why the phrase "it is said" was used in reference to the reported sensations.

The physical principle of the magnetic component of an external electromagnetic field displacing a magnet is sound and there is no reason to disbelieve the reports of people who have had this implant being able to sense a field strong enough to deflect their implanted magnet.

Obviously, the field would have to be strong and reports include a sensation when on a tram (where fluctuating DC currents of hundreds or thousands of amps are present), near electric stove tops powered by AC and from mobile phone towers when a person is within metres of them.

In the context of the examples in the article, it was low-frequency electromagnetic fields (eg, 50Hz or fluctuating DC associated with electrical and electronic equipment) to which these implants were sensitive. There was no suggestion that such implants would be sensitive to higher frequencies such as, for example, radio waves, visible light or x-rays, if that is what Mr Ross infers. (Having said that, it's possible that an implanted magnet may respond to the pulsed nature of mobile phone base station transmissions, particularly GSM, in the near field).

I am sorry that Mr Ross questions my qualifications. You can reassure him that they are all from reputable universities.

On the matter of the "questionable and his extensive qualifications are shown on the masthead, on page 2 of this magazine. We put your question to Dr Maddison and here is his reply:

An AC electromagnetic field has a varying magnetic component. This magnetic field will interact with a magnet and cause it to move. In the case of a DC current-carrying wire, a magnet will orient its N-S axis at right angles to the wire, if there is enough current. This was most famously demonstrated in Oersted's Experiment in 1820 in which it was shown that a compass needle (a magnet) would orient itself away from a current carrying wire (to form a right angle with enough current) – see YouTube video at https://youtu.be/Tr0s5aYpGX0 or many others on the topic.

In the case of an AC magnetic field, a compass needle would swing from one orientation to another, one 180° apart corresponding to opposite phases of the cycle, provided that the needle was capable of responding fast enough or the field was varying at sufficiently low frequency.

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ENELOOP	JAPAN	AA RECHARGEABLE BATTERY (PROD DATE:09/2013)	HR-3UWHA-4BP	17.50/pack	9.50/pack
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REPRAPPRO	USA	ORBIBOT FULL 3D PRINTER KIT	ORNMERCUBA	920.00 ea	395.50 ea
SAMSUNG	UK	8GB SD CARD RASPBERRY PI NOOBS 1.4	NOOBS1.4-8GB	12.10 ea	4.10 ea
DURACELL	THAILAND	AA INDUSTRIAL ALKALINE BATTERIES (EXP: MARCH 2021)	5000394083118	0.75 ea	0.10 ea (Individually packed, order as many as you like)
KINGSTON	CHINA	8GB USB 2.0 DATA TRAVEL DRIVE	DTIG3/8GB	9.50 ea	3.50 ea
DELL	CHINA	VENUE 11 PRO 5130 64GB TABLET	5130-9438	899.00 ea	450.00 ea
SAMSUNG	UK	8GB MICRO SD, ADAPTOR, RASPBERRY PI OS INSTALL	RASPBERRY PI OS 8GB	11.10 ea	4.10 ea
DURACELL	BELGIUM	PROCELL AAA ALKALINE BATTERY (1SPACK) EXP: MARCH 2020	5000394088877	11.50 ea	3.25 ea (10 PER PACK) SPACKS FOR 14.25 (50 BATTERIES)
DURACELL	BELGIUM	PROCELL AA ALKALINE BATTERY (1SPACK) EXP: MARCH 2020	5000394083347	11.50 ea	3.25 ea (10 PER PACK) SPACKS FOR 14.25 (50 BATTERIES)
RS	UK	CAT 5e ETHERNET 4-PAIR TWISTED CABLE 305M REEL	9155WH0305R0S305	290.00 reel	65.00 reel

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Mailbag: continued

Audio playback module solves music problem

In the Ask SILICON CHIP pages of the August 2015 edition, A. H. was asking about a way of generating music to accompany his children's tooth-brushing activities.

A. H. may be interested in the SOMO II MP3 playback module. This is a small PCB (22 x 22mm) with a holder for a microSD card on one side. It can support up to 32Gb of MP3 files in up to 99 folders with 255 files in each. In its most basic form, it needs two pushbuttons and a speaker (there is a built-in mono speaker amplifier).

This gives you next track, previous track, volume up and volume down. A more comprehensive system can have up to 20 pushbuttons to give a wider range of control such as play, stop, random and pause.

Finally, there is a bidirectional serial interface that gives complete control over the module such as folder and track selection.

A. H. could consider using it in one of two (probably more) ways. First, it could have suitable music/songs recorded that can be played as required. Alternatively, considering the number of individual tracks it supports (over 25,000), it may be possible to record fixed pitch notes on individual tracks and, using a microcontroller, play tunes a la MIDI sequencer.

The Audacity program is ideal for working with this device as it can create the required MP3 files.

The SOMO II is available from RS Components for around $33 + GST and freight (Cat. 841-7869).

Richard Jackson
Glenelg North, SA.

sources", presumably in reference to the Biohacking story, I did say in the second paragraph on page 17 that "it is important to note that biohackers are (with some exceptions) primarily of an amateur do-it-yourself background. Institutional involvement is not generally sought nor considered desirable . . .". I am sorry of Mr Ross missed that point. Nevertheless, amateur experimentation or not, what was reported on was real.

Microbee resources on website

After watching the first crowd-funded movie, Kung Fury (Comedy) and seeing the good old Aussie Microbee being used as a hover board and the like, it brought back fond memories from my teenage years and the Microbee. I remember at the age of 14 going to the MicroBee User Group (MBUG) meetings in Burwood, Victoria with a class mate. In total, six trams were involved to get there and I usually got home at midnight. I have fond memories of learning about computers from fellow enthusiasts and some of the things I learned are still with me.

The Microbee was a computer system developed by Applied Technology during the early 1980s and until the early 1990s. The computer had a large following with the "hacker" community. The definition of "hacker" has change a lot since then. "Hacker" basically meant someone who liked to use a soldering iron on their Microbees and those who also liked to know every piece of code in their computer and how the computer worked internally.

The enthusiasm for this little gem was quite large during its peak however the ultimate domination of the PC and clone market slowly put the sales of the Microbee to the bottom percentage of the market. Even though people moved to PCs or Macs, their Microbee was never forgotten. In 2012, Microbee Technology (www.microbeetechnology.com.au) released for sale 100 Microbee kits and these sold out almost instantly

To satisfy my rekindled interest in the Microbee I decided to create a website celebrating this Aussie-made

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computer. Silicon Chip Publications has given me permission to scan and put online many old Microbee articles that appeared in *Electronics Today International* and *Electronics Australia* magazines. Of course, you can purchase ETI and EA articles from the Silicon Chip website.

So if you remember the Microbee or if you have never heard of it, my site is a great source of information and related items. Feedback and content is also always appreciated. Everyone is welcome. I am constantly adding content and updating the site so check it out at http://microbee.uber-leet.com/

Gary Gajic,
Geelong, Vic.

Estimated payback period for a solar installation

Some comments regarding the economics of solar power in response to a number of letters in the August 2015 edition. In the "early days", with large government subsidies it was an easy argument for a 5kW system to pay for itself within 4-5 years. The imperative then was to feed as much back into the grid as possible. Now, with very low subsidies, the imperative is to use your own generated electricity as much as possible to gain the effective value of what the electricity company would be charging.

One other factor has changed and that is that the cost of a solar installation is now about half of what it used to be. Offsetting this is the cost associated with the need to store generated electricity for use during peak energy usage times and at night. In this regard the advent of the more affordable Tesla batteries is timely and the future is off-grid systems.

Following is an estimate of the likely return on investment (if this is all you are interested in) for a 5kWh system, with these "good guess" assumptions: cost of 5kW solar panels plus inverter plus storage system = $15,000; usage = 15kWh/day and utility charge = 36.2c/kWh. From my experience in Melbourne (Silicon Chip, May 2015, remembering that the graphs given for solar energy produced exclude energy used by the house), then for at least six months of the year the system produces in excess of the required 15kWh.

For the other six months the average is around 11kWh. Thus for the whole year there is an average used by the house from the solar system of 13kWh. The utility company would have sold this to the household for a total of $1717. This is a pay back time of 8.7 years or in other words, a return of 11.45% on your investment. Show me where you can get this now.

The above excludes any revenue earned in the high sunlight period of the year. Including this gives an average of an extra 3kWh for six months giving a meagre income of $33 at 6.2c/kWh; not really worth it. The only reason to stay on-grid is if you are unable to generate enough power over the winter period.

Regarding infrastructure costs, everyone pays these regardless of the amount of electricity used. My bills certainly have a separate supply charge item. Given the meagre income now available for new solar installations everyone connected to the network is contributing to the infrastructure.

Dr Alan Wilson,
Glen Iris, Vic.

Tesla car has big battery load

I enjoyed Ross Tester's article on the Tesla car in the June 2015 issue but I'm not sure I want a coal-powered car with 700kg of 121Wh/kg of energy under my feet. Heaven forbid a short in the connections between 18,650 Li-ion cells! At best, unlike that aeroplane, it is always on the ground.

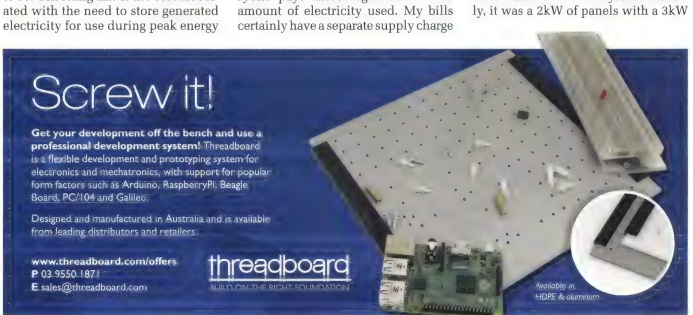
Lumping 700kg of battery around in a 2.1 tonne vehicle seems like a big power overhead. How will they sell in the outback where journeys over 500km are routine? And the $129,000 price tag exceeds my price point!

Anthony Hordern,
Canberra, ACT.

Satisfied with solar power installation

I wait each month for my "fix" by way of Silicon Chip magazine. Now there are a few topics that seem to have been hot for a while, not the least of which is the solar power argument.

We live in a flat in Perth and I managed to convince my landlord to allow us to install a PV solar system. Initially, it was a 2kW of panels with a 3kW



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Mailbag: continued

Kobo reader condemned to oblivion

After reading Geoff Graham's letter regarding Windows 10 software updates in the Mailbag pages of the September 2015 issue, I would like to relate a similar experience I had recently with my Kobo eReader. This is several years old and has spent most of its life in the bottom drawer as I have access to an excellent library of normal books.

On firing it up recently I was going through its index of contents when a message came up on the screen inviting me to "upgrade your software" so I thought well, "Why not?" So I clicked the OK tab and left it for an hour or two. On attempting to resume my reading I discovered that the "upgrade" had in fact deleted the entire contents of the reader, leaving only the Kobo logo.

All attempts to resurrect it have been fruitless and even their website does not respond so it appears these devices have a limited life after which they have to submit to voluntary euthanasia. The accompanying photo demonstrates its non-responsive state.

Reg Haynes,
Australind, WA.

inverter. This worked very well and was duly upgraded to 3kW of panels.

I am very happy with what I had installed even if the location isn't ideal. We have trees at the rear of the property which tend to shield for a while in the winter and the panels have a west-facing aspect.

I have been tracking our power costs for the last seven years. Overall, solar is worth the investment and it is not the "buy back" dollars that count although they are good. Instead, it's the bit that seems to be missing in all the arguments – it's the power you don't have to buy that is forgotten.

The cost of supply continues to rise and will continue to do so, and as long as we are grid-connected there is no relief but there is for the rising cost of a unit of power. Incidentally, I agree – it is power that is exported and totalled as watt-seconds or Ergs in the old units (you remember – a unit of energy!).

On another topic, SILICON CHIP made a nice little audio generator but it would be good to have an audio power/sound level meter unit to allow relative power measurements to be made on an amplifier and loudspeakers, as set up in the average lounge.

I bought a nice Yamaha amplifier a little while ago with all the interface options and upgraded my bass drivers in my speakers. To my ears they don't sound too bad but it would be nice to know how good they are, at least from a frequency response point of view.

I have toyed with replacing my Philips midrange and tweeter with the tweeter from your new Senator system, as they are enclosed in a transmission line enclosure described by J. Linsley Hood many years ago. The apparent response of the cabinet sounds very good but I have never been to quantify that, hence my question.

One further comment on the impressive 12-digit frequency counter that you produced: I thought it would be a good trick to make use of all that precision and display the time when it isn't counting things.

Bill Bool,
Perth, WA.

Comment: if you want to test the frequency response of your hifi system, have a look at the article entitled "How To Do Your Own Loudspeaker Measurements" in the December 2011 issue. You can see a 2-page preview at www.siliconchip.com.au/Issue/2011/December/How+To+Do+Your+Own+Loudspeaker+Measurements SC

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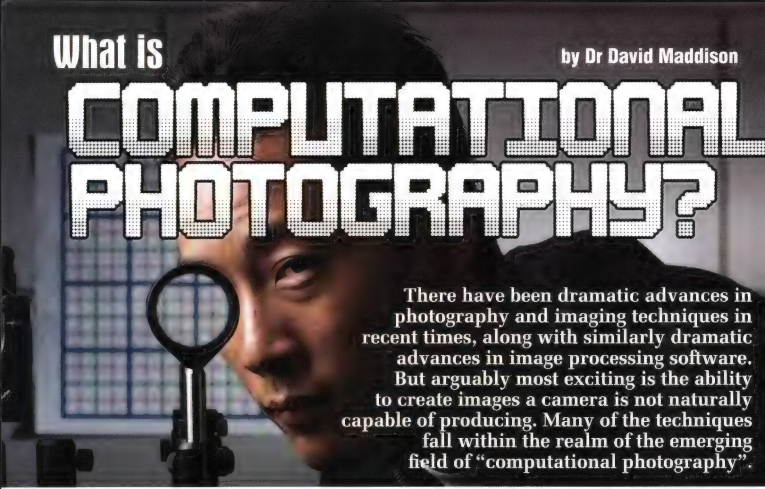
What is COMPUTATIONAL PHOTOGRAPHY?

by Dr David Maddison



There have been dramatic advances in photography and imaging techniques in recent times, along with similarly dramatic advances in image processing software. But arguably most exciting is the ability to create images a camera is not naturally capable of producing. Many of the techniques fall within the realm of the emerging field of "computational photography".

WIKIPEDIA defines computational photography or computational imaging as "digital image capture and processing techniques that use digital computation instead of optical processes".

Essentially, computational photography takes advantage of the substantial computing power now available in portable devices to either augment or replace conventional optical processing. As a result, cameras which use these techniques can take photos in ways previously impossible or impractical.

Probably the single most revolutionary application is that of "lightfield photography" which captures images in a new way, allowing changes to the focus, depth of field and even perspective after the photo has been taken and can also reconstruct captured images in three dimensions.

Other applications inlude novel imaging systems which can operate at a trillion frames per second, see around corners or see through objects. With the exception of "invisibility", all these techniques fall within the realm of computational photography.

Other computational photography techniques which readers may already be aware of, or have even used, include high dynamic range (HDR) photography and panoramic stitching.

High dynamic range imaging

High dynamic range (HDR) imaging allows the recording of a greater range of luminosity or brightness than an imaging system would normally allow but which the human eye can easily perceive. Examples are scenes in which there is an extreme range of luminosity such as a backlit object or person or an indoor scene with bright light coming through windows or a combination of sunlit and shaded areas.

Some high end cameras and smart phones have built-in HDR functions (and there also some Apps for smart phones) although many photographers prefer to do their HDR processing manually, as they are not satisfied with the built-in functions of the cameras.

The basic technique of HDR imaging is to first acquire a series of images of the same scene with different exposure settings. Many consumer digital cameras are able do this automatically ("exposure bracketing") but it can be done manually on any camera where exposure can be controlled. Such a series of photos will ensure that there is at least one photograph in which part of the scene of interest is correctly exposed and collectively, the entire set of photos will have all parts of the scene exposed correctly. It is then a matter to combine these pictures into one composite image.

Interestingly, HDR photography was invented in the 1850s by Gustave Le Gray. He took pictures that contained both sea and sky and took one negative of the sea and another of the much brighter sky and combined them to form a single picture. The desired luminosity range could not be recorded for such a scene using the photographic media of the time.

If you are interested in trying HDR photography there are a number of online tools you can use to generate photographs and also tutorials.

Panoramic imaging

Panoramic cameras were invented as early as 1843 and often had specialised gears and curved film planes to pan across a scene exposing a portion of the film as they rotated. Today, panoramic imaging is a common feature found in

many modern digital cameras and phones and involves software to "stitch together" a number of separate images to make one single image with a wide field of view.

There also smart phone Apps, software suites and free online services to do this, eg, Hugin (http://hugin.sourceforge.net/) and Panorama Tools (http://panotools.sourceforge.net/) are two free software suites for making panoramas and stitching photos.

Panoramic photography can be greatly facilitated by a special panoramic tripod head. Some are commercially available and others can be home-made. Some websites related to home-made heads are at http://teocomi.com/; build-your-own-pano-head/; www.worth1000.com/tutorials/161123/tutorial and www.peterloud.co.uk/nodalsamurai/nodalsamurai.html

A popular commercial non-automated panoramic head is the Panosaurus: http://gregwired.com/Pano/pano.htm

If setting up a panoramic head it is desirable to find the "nodal point" to ensure there is no parallax error in the image. See video *"Finding a lens nodal point and shooting panoramas"* https://youtu.be/lpFzBq0g7pY

A popular technique related to panoramic photography is the creation of gigapixel resolution images. For info on this technique, just Google "make your own gigapixel image". You can also read the article about military use of gigapixel photography in the article entitled *"ARGUS-IS Wide Area Persistent Surveillance System"* (Silicon Chip. December 2014) www.siliconchip.com.au/Issue/2014/December/The+Amazing+ARGUS-IS+Surveillance+System

Leonardo da Vinci and light-field photography

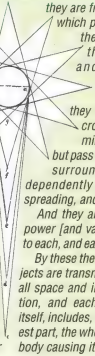
Leonardo da Vinci realised that light from an object arriving at a viewer contains all the information necessary to reproduce any view possible at that point.

That is, he recognised the concept of light rays and that if enough information could be collected any image could be formed after the fact of information collection that had any desired depth of field or focus.

He wrote "The...atmosphere is full of infinite pyramids [light rays] composed of radiating straight lines, which are produced from the surface of the bodies....and the farther they are from the object which produces them the more acute they become and although in their distribution they intersect and cross they never mingle together, but pass through all the surrounding air, independently converging, spreading, and diffused.

And they are all of equal power [and value]; all equal to each, and each equal to all.

By these the images of objects are transmitted through all space and in every direction, and each pyramid, in itself, includes, in each minutest part, the whole form of the body causing it."



da Vinci's 15th century depiction of what we now know as the light-field. From "The Notebooks of Leonardo da Vinci" edited by Jean Paul Richter, 1880.

High dynamic range picture by Michael D. Beckwith of the Natural History Museum in London. This would not be possible with normal photographic techniques; with a regular photo, either the highlights would be over-exposed or the shadows would be under-exposed. www.flickr.com/photos/118118485@N05/12645433164

An example of a "panoramic" photo: Sydney Harbour Bridge at night. Some cameras have this mode inbuilt; others require after-shot software attention. https://upload.wikimedia.org/wikipedia/commons/e/ea/Sydney_Harbour_Bridge_night.jpg

Previous articles on gigapixel photography were published in the February 2004 & September 2011 issues of SILICON CHIP: *"Breaking The Gigapixel Barrier"*, by Max Lyons; www.siliconchip.com.au/Issue/2004/February/Breaking+The+Gigapixel+Barrier and *"World Record 111-Gigapixel Photograph"*, by Ross Tester; www.siliconchip.com.au/Issue/2011/September/World+Record+111-Gigapixel+Photograph

For general image manipulation, Adobe Photoshop is the standard image processing software and it can be used to manually stitch photos into a panorama. There are a number of free alternative although they might not be as feature-rich as Photoshop. GIMP, for GNU Image Manipulation Program (www.gimp.org/) is a free image processing program that works on many platforms and is almost as powerful as Photoshop.

Other free programs are Photoshop Express Editor (www.photoshop.com/tools) which is an online tool but also has Apps for smart phones; Pixlr Editor or Pixlr Express https://pixlr.com/ also online and paint.net (download from www.getpaint.net/index.html).

Light-field and lens-less photography

HDR and panorama photograaohy use a standard camera with a lens, iris, shutter and an image sensor. But now there are cameras in production or under development which use either a micro-lens array in front of an image sensor or multiple lenses, or dispense with the lens altogether.

Imagine a camera in which you could change the focus, depth of field or even the perspective ***after*** you have taken the picture and left the scene. This can be done right now with a light-field camera, also known as a plenoptic camera.

The lens in a conventional camera focuses light rays arriving at different angles onto the film or sensor, such that a two-dimensional image is formed where the subject is in sharp focus. Only the colour and intensity of the light over the film or sensor is recorded and thus no depth information is retained. All that is recorded is the one point of view and the focus and depth of field as determined by the lens setting at the time the photograph was taken.

By contrast, as well as recording colour and intensity, a plenoptic (or light-field) camera also captures information concerning the direction from which light rays arrive. This means that the image can be re-processed later, to produce a new two-dimensional image or extract three-dimensional information (eg, to form a "point cloud").

In a light-field photograph, enough information is recorded about a scene such that, with appropriate software, the depth of field or focus can be changed after the picture is taken. For example, all parts of a scene could be bought into focus, or just parts of a scene such as only those objects at a middle distance. Or if the lens was not properly focused at all, the focus can be improved. See the three images below for an example of what can be done with an image captured in thie manner

It is also possible to generate a plenoptic image using an array of multiple conventional cameras and combining their images with computational methods or using one camera that is moved to a variety of positions at which images are taken (which would work only for unchanging scenes). Plenoptic cameras, however, can yield 3D information from a single image and single camera from one position.

Leonardo da Vinci in the 15th century was the first to recognise the idea that light arriving at a given location contains all the information required to reproduce all possible views from that position (see box on previous page). What does that actually mean?

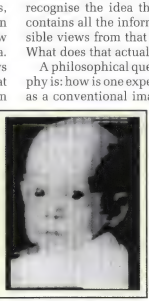
A philosophical question in regard to light-field photography is: how is one expected to "use" the image? If it is printed as a conventional image, only one possible interpretation (depth of field, perspective) will be rendered. Should the image remain online and interactive where all possible interpretations of the image can be viewed?

By the way, you may have noticed that there are some similarities between light-field photography and stereoscopic photography, which has been around for a long time. However light-field photography allows for a lot of new possibilities so that is what we are going to concentrate on.

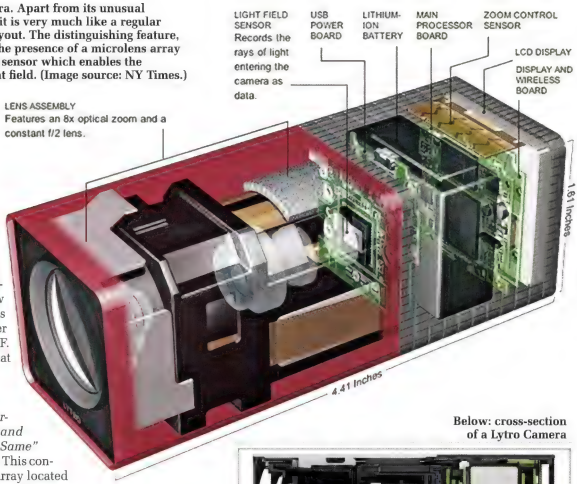
The first digital scanned image

The first digital scanned picture was created in 1957. The image resolution was 176x176 or a total of 30,976 pixels and in black and white only but it produced a recognisable image. Multiple scans at different thresholds produced some grey scale as shown in the image.

The group that lead this work at the US National Bureau of Standards was Russell Kirsch. The computer used was SEAC (Standards Eastern Automatic Computer) and it stored 512 words of memory in acoustic delay lines, with each word being 45 bits.



Inside a Lytro camera. Apart from its unusual rectangular design, it is very much like a regular digital camera in layout. The distinguishing feature, not visible here, is the presence of a microlens array in front of an image sensor which enables the recording of the light field. (Image source: NY Times.)



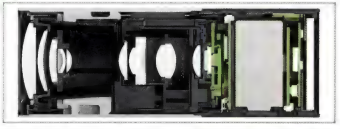
History of light-field photography

Light-field photography is not new either – the idea has been around for over 100 years. In 1903, F. E. Ives described what some consider to be the first light-field camera in the US Patent entitled *"Parallax Stereogram and Process of Making Same"* (US Patent 725,567). This consisted of a pinhole array located just in front of the focal plane in a conventional camera. Each pinhole image captured the angular distribution of radiance.

G. Lippmann in 1908 introduced "integral photography" and replaced the pinholes of Ives with lenses. (Lippmann, incidentally, was a Nobel Laureate for colour photography and Marie Curie's thesis advisor). See http://people.csail.mit.edu/fredo/PUBLI/Lippmann.pdf for a translation of his original paper.

For those interested, a presentation of the history of light-field photography by Todor Georgiev, *"100 Years Light-Field"* can be read at www.tgeorgiev.net/Lippmann/100_Years_LightField.pdf

Below: cross-section of a Lytro Camera

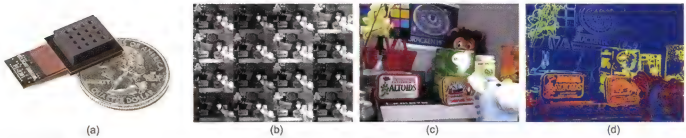


The Lytro Camera

The Lytro plenoptic camera is essentially a conventional camera in terms of the geometry of its components but it has a micro-lens array placed in front of the image sensor. The micro-lens array has at least 100,000 separate lenses over the image sensor (Lytro does not disclose the exact number) generating at least 100,000 slightly different micro-images of perhaps one hundred or more pixels each, all from slightly different angles. The pitch of the micro lenses (the centre to centre distance) is said to be 13.9 microns.

The information in this large number of individual images is mathematically processed in the camera, yielding an image for which the focus, depth of field and the per-

Photograph showing the variable depth of field (DoF) capability of a single Lytro camera image. Slight changes in perspective are also possible. Screen grabs from https://pictures.lytro.com/lytro/collections/41/pictures/1030057



(a) (b) (c) (d)

(A) The PiCam Camera Array Module against a US Quarter coin (24.3mm diameter), (B) raw 4x4 array of images each of 1000 x 750 pixels resolution or 0.75MP, (C) parallax-corrected and "super- resolved" 8MP high resolution image and (D) high resolution 3D depth map with different colours corresponding to different distances from the camera.

spective can be changed after the picture is taken. A disadvantage of this type of technique is that the final image is of much lower resolution than the image sensor. While Lytro have given no particular specifications, it has been estimated that in one model of Lytro camera, the Illum, the sensor has a 40 megapixel resolution while the images themselves have about 1.1 megapixels of resolution. (See discussion at www.dpreview.com/articles/4731017117/lytro-plans-to-shed-jobs-as-it-shifts-focus-to-video).

When you think of it, having 100,000 separate images, all from a slightly different perspective, is just a scaled up version of human vision, with two eyes giving a slightly different perspective. Or it might be compared with the compound eye of an insect.

Each of the thousands of individual eye elements or ommatidia in an insect eye contain between six and nine photoreceptor cells, very roughly equivalent to pixels. Interestingly, insect compound eyes are also of relatively low resolution. To have a resolution the same as human eyes would require a compound eye with a diameter of 11 metres!

Lytro have an image gallery on their website where you can view and manipulate individual images from Lytro cameras. See https://pictures.lytro.com/

In addition to the traditional camera specifications such as lens focal length, lens f-number, ISO speed range, sensor resolution and shutter speed range, there is an additional specification for plenoptic cameras which is the light-field resolution in megarays which refers to the number of individual light rays that can be captured by the sensor. The Lytro Illum model, for example, has a capability of 40 megarays per picture.

The Lytro camera was developed out of the PhD work of

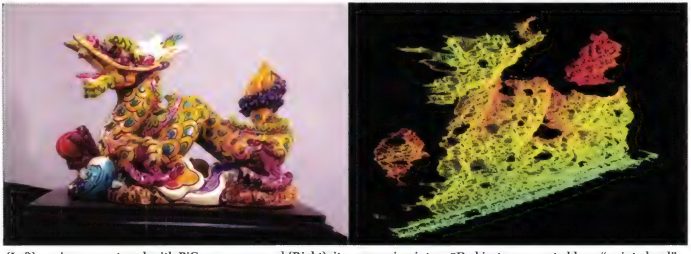
The 16 lens array of the PiCam and the associated RGB filters comprising of sets of two green, one red and one blue filter forming four 2x2 sub-arrays.

Dr Ren Ng who started his PhD studies in 2003 and founded Lytro in 2006, shipping the first cameras in 2012.

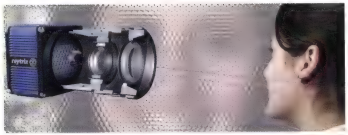
PiCam Camera Array Module

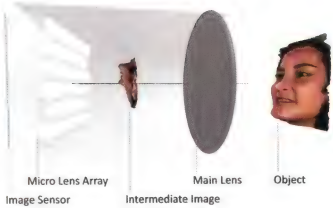
Recognising that photography from mobile phones is by far the most popular form of photography today, Pelican Imaging (www.pelicanimaging.com) is developing imaging sensors for these devices. The problem with current mobile phones is that they are so thin that there is insufficient depth to have a sophisticated lens system to provide extremely high quality images.

The PiCam uses 16 lenses over one image sensor, yielding sixteen slightly different images instead of one. Each of the 16 different images effectively represents a different camera with a sensor area assigned to it of one sixteenth of the total sensor area. Unlike the Lytro which uses a micro-lens array



(Left): an image captured with PiCam camera and (Right); its conversion into a 3D object represented by a "point cloud".





(Above): Raytrix industrial light-field camera.
(Right): The imaging scheme used in Raytrix camera.

with 100,000+ lenses, 16 non-micro lenses are used.

Now, the smaller an image sensor area is, the smaller the size of lens that can be used to project an image onto it. This means that instead of having one larger lens to project an image onto a larger sensor, a series of smaller lenses can be used to project a series of images onto a smaller sensor area. This enables a significant reduction in the size of the lens required and a corresponding reduction in the thickness of the device.

This relationship between lens size and sensor size can be seen with regular digital cameras in which larger lenses are required as the image sensor is increased in size. It also means that cameras with smaller sensors can have larger zoom ratios; to achieve similar zoom ratios on a camera with a larger sensor such as an SLR would require impossibly large lenses. Of course, the disadvantage of having a smaller sensor size is that it gathers less light and so requires longer exposures, and the resolution is generally lower.

A further innovation of the PiCam is to remove the colour filters from the image sensor and have them within the lens stack. This means that each of the 16 sensor areas will image one particular colour range only; red, green or blue.

Having one colour range for each lens dramatically simplifies the design as each lens only has to operate over a restricted range of wavelengths rather than the whole visible spectrum. The lens for each colour is optimised for that colour's range of wavelengths. Image quality is also improved as chromatic aberration is minimised.

Not having a filter on each individual pixel on an image sensor also has the advantage that the sensor can accept light from a wider range of angles than if a filter were present. This improves light gathering efficiency (to allow greater sensor sensitivity) and reduces crosstalk between pixels which can cause image blur.

The software associated with the camera adjusts for parallax errors between the 16 different images and uses a "super-resolution" process to reconstruct a final 8MP image from the individual images, taking into account various degradations that will occur during the acquisition of an image.

The difference in optical configuration between this camera and the Lytro is that with the Lytro a micro-lens array is placed at the focal plane of the main (conventional) lens and the image sensor is placed at the focal plane of the micro-lens, while in the PiCam the sensor is at the focal plane of the one 16 lens array.

As with other light-field cameras, an image can be captured first and focused later, avoiding the delay that occurs with focussing conventional cameras.

The PiCam is a 3D-capable device (as are all light-field cameras, in theory) and can generate both depth maps and "point clouds" representing the 3D object and this data can then be converted to a conventional 3D mesh.

As a hand-held 3D capture device, the potential applications are very interesting. For example, a "selfie" from a camera such as the PiCam could be emailed to someone to be reproduced on a desktop 3D printer....

For further information and details of the image reconstruction process see the video "*Pelican Imaging SIGGRAPH Asia 2013: PiCam (An Ultra-Thin High Performance Monolithic Camera Array)*" https://youtu.be/twDneAffZe4. Also see "*Life in 3D: Pelican Imaging CEO Chris Pickett Explains Depth-Based Photography*" https://youtu.be/CMPfRR4gHTs

For some sample images, see www.pelicanimaging.com/parallax/index.html

Raytrix

Raytrix is a German firm (www.raytrix.de) specialising in light-field cameras for industrial use and specifically targeting research, microscopy and optical inspection in manufacturing operations.

Unlike the Lytro and the PiCam, the Raytrix camera uses a scheme devised by Todor Georgiev that he calls "Plenoptic 2.0" in which a micro-lens array is placed in an area other than the focal plane of the main lens. With this optical arrangement, the number of micro-lenses is not a limiting factor in the resolution of the final image and in theory at least, could approach the sensor resolution.

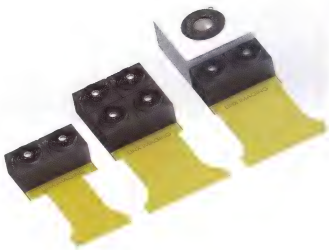
While Plenoptic 2.0 achieves a higher proportion of the native sensor resolution than, say, the Lytro camera, substantial computation is required to achieve that result and the camera has to be connected to a high-end computer with a specialised graphics card for processing the video data. In the case of the Lytro camera, video processing is done within the camera.

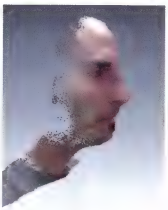
The micro-lens array in the Raytrix cameras has several different focal length for each of the 20,000 micro-lenses and this allows the depth of field to be significantly extended.

In addition to still photography, Raytrix cameras can be

Scanography

The field of "scanography" involves using a flat-bed scanner to produce images for artistic or technical purposes. Flat objects such as leaves can of course be scanned but since a flatbed scanner has a depth of field of about 12mm, small 3D objects can be scanned as well. Three dimensional images can also be generated using appropriate software. Some image examples are shown at https://commons.wikimedia.org/wiki/Category:Scanography





(Left): several versions of LinX imaging devices from before Apple Inc. purchased the company.

(Two images above): 3D point cloud created by a LinX camera from a single frontal image.

used to generate 3D video and are also being used in microscopy where they can video living micro-organisms and ensure the whole organism is kept in focus.

LinX Computational Imaging

LinX Computational Imaging is an Israeli company which was recently purchased by Apple Inc, so their website no longer exists. LinX developed a number of multi-aperture cameras for mobile devices that had reduced height to allow their incorporation in thin phones.

LinX offered several camera modules including a 1x2 array which had a colour and monochrome sensor for better low light performance and basic depth mapping, a 1+1x2 array with two small aperture cameras to make a high quality depth map and a larger camera with a 2x2 array for better quality depth maps, high dynamic range, better low-light performance and improved image quality. It is highly likely that this technology (or a spin-off from it) will end up in future iPhones.

Corephotonics

Corephotonics Ltd (http://corephotonics.com/) is another Israeli company. It offers solutions with novel optical actuators and optical designs and which also involve computational photography. Its offerings are generally customised for particular clients but they are built around a dual camera module incorporating two 13MP sensors, a Qualcomm Snapdragon 800 processor and special computational photography algorithms.

One of the sensors has a fixed focus telephoto lens and the other has a wide-angle lens. The image data from both is seamlessly integrated to provide great image sharpness and up to five times optical zoom. This camera system can also do high dynamic range imaging with one shot.

Superior performance in optical zoom, image noise, focus error and camera movement reduction are possible. It is also capable of depth mapping.

Rambus

The Lytro, PiCam, Raytrix, LinX and Corephotonics cameras mentioned above all have some type of lens as an optical element to focus the image.

Rambus (www.rambus.com) have used a spiral diffraction grating on the surface of a sensor chip which also incorporates processing hardware to construct a lens-less computational imaging device. The output of the grating is meaningless without computer reconstruction.

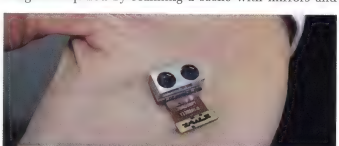
To understand how this device works we will first consider its predecessor. A device called a planar Fourier capture array (PFCA) was invented by Patrick Gill while a student at Cornell University. This lens-less device consisted of an array of pairs of optical gratings on top of an array of photodiode image sensors. Consider that a pair of optical gratings is equivalent to a pair of picket fences. Light will only pass through the gaps at angles at which the gaps in both fences are aligned with each other.

By having the pairs of optical gratings on the chip arranged at a variety of angles, it was possible to have photodiodes activated through the full possible range of angles of incident light impinging on the chip. The image data was then processed to yield the original image. A disadvantage of this device was limited resolution and spectral bandwidth.

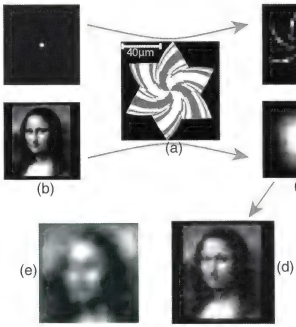
Patrick Gill went on to work for Rambus where he addressed the limitations of the PFCA device. He developed a new type of diffractive element called a "phase antisymmetric grating" which is based upon a spiral pattern. Unlike the PFCA in which a pair of diffraction gratings correspond to only one angle of light and sensitive to limited light frequencies, photodiodes under the spiral grating can be sensitive to light from all angles and light frequencies. These devices promise much better quality images in smaller device packages than PFCAs.

Single pixel cameras

A single pixel camera, as the name implies, acquires an image with a sensor with just one pixel of resolution. The image is acquired by scanning a scene with mirrors and



Corephotonics dual camera module for mobile devices.



(a) Phase anti-symmetric grating and how a point of light (top left) is sensed by the imaging array (top right); (b) image of the Mona Lisa and how it is sensed (c) on the imaging array; (d) image of Mona Lisa after data from array is processed; (e) same image as it would appear when generated from a PFCA device showing inferior quality.

then mathematically reconstructing the original image. One might ask why you would want to do this but it does have some advantages and is the subject of active research.

The concept falls under the general category of "compressed sensing" or "sparse sampling". The key difference between a conventional megapixel camera and a single pixel camera is that vast amounts of data are collected with the megapixel camera and then essentially thrown away in the compression process after the image is recorded while in a single pixel camera, only information that is required is recorded. It achieves this by compressing the information in the image before the data is recorded with the sensor's built-in hardware.

Rice University, among others, has done pioneering work in single pixel imaging.

The basic principle of the single pixel camera is that light from a scene is reflected from a digital micro-mirror device (DMD) onto a single-pixel sensor such as a photodiode. The DMDs in many video projectors contain thousands of individually controllable microscopic mirrors in an array. The mirrors can be made to either reflect light in a certain direction or away from it.

Using the DMD there are two ways an image can be acquired, depending upon how the mirrors are driven.

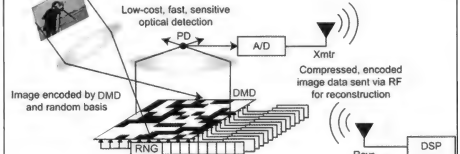
One way is to acquire an image in raster mode like in a CRT (as in an old TV or computer monitor). This is done by causing the first mirror in the DMD array to reflect light onto the sensor while all other mirrors reflect light away from it. In the next stage, the second mirror in the array reflects light onto the sensor while all the others reflect light away and so on for all the mirrors, about 10 million of them. Eventually an image is built up which will contain all the information of the original scene. That data could then be transformed to a compressed image in the conventional way.

We know from conventional imaging that there is a lot of redundant data in most scenes that does not need to be recorded.

For example, there is no need to record all pixels representing the sky in a scene because, simplifying things, we can say a certain patch of sky consisting of say several thousand pixels can all be assigned the one colour. Compression algorithms do that and dispose of much of the original data.

This leads us to the second and preferred way to drive the DMD array to acquire compressed data. This is called the compressed sensing mode. The mathematics are quite complex and beyond the scope of this article but basically what happens is as follows.

An image can be represented as a series of wavelets, or wave-like oscillations. To construct, say, a 10MP image with wavelets, would require the same number of wavelets and a lot of data. It turns out, however, that, as noted above, most realistic images contain redundant data. It might turn out that for a 10MP image there would only be 500,000 significant wavelets and the remaining 9,500,000 seem insignificant noise, the removal of which would go



Single pixel camera from Rice University. The DMD is the digital micro-mirror device, the PD is the photo-detector (the single pixel), the DSP is the digital signal processor and the RNG is the random number generator. In this case the data is transmitted wirelessly to the DSP from the device.

The Pinhole Camera

Lens-less imaging is one of the oldest ideas in photography and F. E. Ives developed the first plenoptic camera with a series of pinhole images, as described in the text. The simplest camera uses a "pinhole" to form an image, although exposure times are long due to the small amount of light that gets through. There are many instructions on the web for making your own pinhole camera such as at www.kodak.com/ek/US/en/Pinhole_Camera.htm

Pinhole cameras are also commercially available from a number of sources such as www.pinholecamera.com for beautifully crafted models or you can get mass-produced models on eBay quite cheaply (search "pinhole film camera"). An intriguing use of pinhole cameras in modern times is their use in "solargraphy" to capture the path of the sun as it moves across the sky. See www.solargraphy.com

Make your own light-field camera

Interested in making your own light field camera? Here are some web sites to look at. Mats Wernersson describes how he made his at http://cameramaker.se/plenoptic.htm

Here is an article that describes how to convert video of a still image with changing focus to something that resembles a light-field photograph but is not a real one: "*Turn any DSLR into a light field camera, for free*" www.pcadvisor.co.uk/how-to/photo-video/turn-any-dslr-into-light-field-camera-for-free-3434635

unnoticed.

This is the basis of image compression although the algorithms are much more complex than described.

The objective of the compressed sensing mode is to acquire compressed data without the need for post-processing.

It turns out mathematically that if instead of using raster mode scanning, which acquires the maximum amount of uncompressed image data, one takes random measurements from a scene in a certain manner, it is possible to build up an image with far fewer than the original 10 million measurements as mentioned above.

Using a random number generator, the software creates a random tile pattern in the micro-mirror array. The first measurement is made and then another random pattern is generated and another measurement taken and so on. Light from the random tile pattern is reflected onto the single pixel sensor and sent to the digital signal processor.

After processing of this data, an image will be built up that is indistinguishably close to that from the original raster methods but with approximately 20 percent of the data or far less than that needed for the raster measurements.

The data from the random tile pattern is said to be mathematically incoherent with wavelets within the image and therefore automatically compressed at the time it appears at the single pixel detector therefore there is no need to compress the images that come out of the camera.

For more details, see https://terrytao.wordpress.com/2007/04/13/compressed-sensing-and-single-pixel-cameras/

While conventional digital photography is suitable for a vast number of applications, the advantages of single pixel photography are as follows:

- The single pixel sensor requires very little power and large amounts of CPU power are not required to drive millions of pixels or process the data.
- Data that comes from the sensor is already compressed.
- The device can be made at low cost as there is no large scale sensor to fabricate.
- The device can be miniaturised and with low power consumption and low cost, could be used for persistent surveillance applications, eg, environmental monitoring and defence.
- A single pixel sensor can be optimised to be sensitive to certain ranges of frequencies. Making a megapixel sensor that is sensitive to visible light is straightforward with conventional sensor technology but much more difficult with sensors in, say, the IR or UV bands. Making a single pixel sensor sensitive for those bands is much easier.
- Lens-less single pixel photography is also possible, as recently demonstrated by Bell Labs.

Google is also apparently interested in single pixel photography, perhaps for use in wearable devices and recently filed a 2015 patent, see http://google.com/patents/US20150042834

A single pixel camera using an Arduino and components made with a 3D printer can be seen at: www.gperco.com/2014/10/single-pixel-camera.html and http://hackaday.com/2015/01/21/diy-single-pixel-digital-camera/

Not a single pixel camera but also of interest; researchers at the Massachusetts Institute of Technology in the area of light-field photography have combined an old bellows view camera and a flatbed scanner as an imaging sensor.

See http://web.media.mit.edu/~raskar/Mask/

Cloaking – making things "invisible"

While not strictly computational photography, an interesting development in optics is a relatively simple method to give a certain area the illusion of invisibility using lenses. This method was developed at the University of Rochester and may have practical applications such as enabling a surgeon to see "through" his hands as he operates.

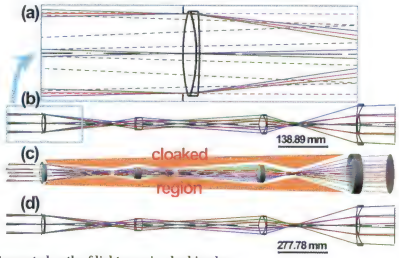
For a demonstration, see "*The Rochester Cloak*" https://youtu.be/vtKBzwKfP8E

For those unfamiliar with Star Trek, the device is referred to as a cloaking device after the technology used to render a space ship invisible in that show. See www.startrek.com/database_article/cloaking-device

Femto-photography

Femto-photography is a new field in which the propagation of light can be visualised using frame rates of around half a trillion frames a second.

The technique involves the use of a titanium sapphire laser as a light source that emits approximately 13 nanosecond long pulses and detectors that have a timing accuracy



Computed path of light rays in cloaking lens arrangement. Image from "Paraxial ray optics cloaking" http://arxiv.org/pdf/1409.4705v2.pdf (See referenced text for details.)

in the order of picoseconds. It also requires a "streak camera" which can measure the variation of the intensity of an ultra-fast light pulse with time. Mathematical techniques are used to reconstruct the image.

As the exposure times at such frame rates are so short (around 2 trillionths of a second), it is not possible to capture imagery without repeating an exposure many millions of times. This means that whatever is filmed has to be repeatable, such as a light pulse striking an object. Random events such cannot be filmed as they are not repeatable.

To give an idea of the sort of time periods involved, bear in mind that light travels 0.30mm in a trillionth of a second or picosecond (10^{-12} seconds) in a vacuum.

To watch a video of the propagation of a light pulse see the videos "*Visualizing Light over a Fruit with a Trillion FPS Camera, Camera Culture Group, Bawendi Lab, MIT*" https://youtu.be/9RbLLYCiyGE and "*Laser pulse shooting through a bottle and visualized at a trillion frames per second*" https://youtu.be/-fSqFWcb4rE

Looking around corners with femto-photography

Using the principles of femto-photography as described above, researchers in the same group have developed methods to image objects that are obscured and cannot be directly seen, by analysing "light echoes".

The principle is that if an area is illuminated, some photons from even obscured areas will return to the source through multiple bounces.

Knowing the time that photons were emitted in the form of a laser pulse and given the finite speed of light and the return time of the photons, it is possible to computationally determine the shape of an unseen object they bounced off.

Possible applications for this technique include seeing around corners in endoscopic procedures or other medical imaging or even seeing around blind corners when in a car, or in search and rescue applications where fire fighters might have to see around a blind corner, among many others.

A video demonstrating the technique is "*CORNAR: A camera that looks around corners*" https://youtu.be/8FC6udrMPvo

Build your own "cloaking device"

You can build your own "cloaking" device similar to the device developed by the University of Rochester. They provide a generic description on their web page at http://www.rochester.edu/newscenter/watch-rochester-cloak-uses-ordinary-lenses-to-hide-objects-across-continuous-range-of-angles-70592/ (that description is repeated many times in other locations).

A document on how to build the device is at http://nisenet.org/sites/default/files/RochesterCloak-NISENet.pdf

You will need appropriate sources and mounting hardware for the lenses and laboratory grade lenses and components can still get very expensive. A kit of lenses is available at www.surplusshed.com/pages/item/l14575.html

(**Note**: this kit has not been tried or tested by SILICON CHIP).

Conclusion

We have surveyed a variety of techniques of computational photography, its history and some of the capabilities it offers.

Computational photography can generate extremely information-rich images that can lead to many new uses such as simple 3D photography. Many of these advances will end up in cameras in mobile devices which will be used to construct 3D models of the environment.

As time goes on, fewer photos will be taken on "conventional" cameras due to the high quality achievable with new miniaturised mobile phone cameras. Of course, photography will still be an art and that should always be remembered but artistic possibilities with these new technologies will be greatly expanded. 3D photography and movie making will be much easier and it will be easy to generate 3D models of the environment.

3D photos such as "selfies" could even be taken and emailed to others who could use a printer to print the picture in 3D. New imaging technologies such as lens-less photography and its associated miniaturisation will continue to develop. Recording of all life's events will become pervasive and recordings will have unprecedented detail and we will have more information about our environment than ever before. SC

Experimental setup to view object behind barrier. The object is invisible to the camera and must be imaged by reflected photons that may have travelled back to the camera by multiple different paths. Frame grab from https://youtu.be/JWDocXPy-iQ. At right is a computationally reconstructed image of an object hidden behind the barrier.

Need power when the sun don't shine . . . or when the grid fails?

A LARGE, "REAL WORLD" *HYBRID* SOLAR SYSTEM

A major drawback of conventional (grid-tied) solar power systems is that they deliver no power when the grid fails. So if you have a blackout during and/or after a natural disaster, such as a bushfire, flood, cyclone or severe thunderstorm, you may be without electricity for days or even weeks. But if you have a hybrid solar system you can produce your own electricity when other people have none. You can even have "solar generated" electricity at night. . .

By LEO SIMPSON

With a hybrid solar system, in addition to the PV panels and grid-tied inverter normally found in a typical domestic solar system, an inverter/charger and battery bank are required.

Even with a quite moderately sized battery bank, a hybrid system can typically double a household's "self-consumption" of solar-generated energy. An appropriately-sized system that can supply a household's needs until after 10pm offers the possibility of moving to time-of-use metering, which can halve the price of purchased power.

This system can easily supply this amount of power.

If you can run the household or business from the solar-generated power during the day and recharge the batteries to carry the load until 10pm or later, you can have very real savings in the cost of your purchased power.

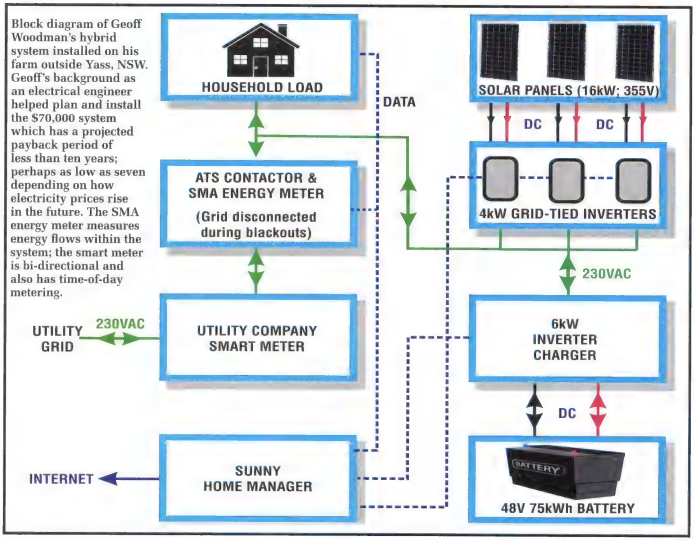
The trade-off, of course, is the much larger initial investment in a hybrid system, particularly in storage batteries – in this system, around $50,000 worth! However, recent developments are likely to bring significant reductions in the prices of batteries in the future.

A hybrid solar power system can deliver enough power to satisfy normal household loads during the day when the sun is shining. At the same time, assuming enough power is coming from the solar panels, it charges its batteries. Any excess power can be exported to the grid. When the sun sets, the batteries provide the household electricity needs and depending on the load and state of charge of the batteries, some power may be drawn from the grid.

When the sun rises in the morning, the cycle repeats. The first priority is to supply any household loads, then

The ~$50,000 bank of 24 x 2V gel cells, all connected in series to achieve a 48V DC, 75kWh battery. Inset at top is the label on the cells.

Mounted below the solar panels and through the wall from the battery bank is the electronics: the three red boxes are the 4kW grid-tied inverters, with isolating switches underneath. Their 230VAC outputs are combined and fed to the charger (yellow box) as well as to the ATC contactor (underneath), thence to either the household load or via the smart meter back to the grid. The amount which goes to each is prioritised, with household use taking precedence, then battery charging, then feed back into the grid. Note the heavy steel posts which protect the electrics in case of an errant vehicle/trailer/etc.



Block diagram of Geoff Woodman's hybrid system installed on his farm outside Yass, NSW. Geoff's background as an electrical engineer helped plan and install the $70,000 system which has a projected payback period of less than ten years; perhaps as low as seven depending on how electricity prices rise in the future. The SMA energy meter measures energy flows within the system; the smart meter is bi-directional and also has time-of-day metering.

to recharge the batteries and when the batteries are fully charged, export any excess power to the grid. Sound simple, doesn't it? In practice, it is a lot more complicated and the system is a lot more expensive than a basic grid-tied solar system of similar capacity.

This article came about as a result of the Publisher's Letters in the March & August 2015 issues on the drawbacks of grid-tied inverters, and the resulting letters in the Mailbag pages of subsequent issues.

A real hybrid system

Long-time reader and electrical engineer, Geoff Woodman, sent in some details of his hybrid solar system which had been installed on his property near the New South Wales country town of Yass. This type of system is quite new to Australia so I recently visited him for a closer look.

This system is still grid-tied and so does not necessarily need a very large battery bank nor the option of a diesel generator to charge those batteries during possible long periods of inclement weather, when the solar panels may produce little power. And while the system is grid-tied, there is a limit of 2.5kW on the power that can be exported to the grid at any time . This is set by the voltage losses in the power lines to the property.

This system could quite easily be converted to a wholly stand alone ("off grid") system but would then lose the advantages of having a backup grid supply and being able to sell excess power back to the grid. But at the derisory rate of 6c/kWh, the latter is not a huge incentive.

It would, however, save the "standing" or "supply availability" charge which the utilities charge everyone who is connected – even if you use virtually none of their power. Currently, this charge is between about 70c and $1.75 per day, depending on your supplier and location – so it could be as high as $600 or more each year.

Geoff's system has 54 300W LG solar panels and three "Sunny Boy" SB4000 inverters made by SMA Solar Technology AG. These are normal grid-tied inverters rated at 4000W each (AC side). Each inverter has two DC inputs, each with its own MPPT (Maximum Power Point Tracking) controller. This provides six MPPT inputs.

The maximum DC input to each inverter is 12kW, so it is possible have a PV array with a peak output well in excess of the inverter's rated 4000W AC output. In fact, it's good practice to oversize the PV arrays by about 30% relative to the AC output of the inverter, as most fixed panels only deliver their maximum output for a limited time each day, in bright sunlight; on cloudy days, they may deliver much less output.

The Sunny Boy inverters have Bluetooth and/or serial data ports that provide data on the power delivered by the inverter and provision to limit the power output by adjust-

Three "Sunny Boy" SB4000 inverters take the DC from the solar panels and feed 230VAC into the system. They have a user-friendly LCD screen to show the power being generated, are virtually noiseless in operation and can be used in grid-tied, stand-alone and hybrid systems.

The "heart of the system" is the Sunny Home Manager. It provides an overview of all energy flows within the solar installation and uses this information to direct energy to the location which needs it, in order of priority (household power has highest priority, then battery charging, then output to the grid).

ing the output voltage. The AC outputs of the three Sunny Boys are effectively wired in parallel.

The solar panels are mounted in six strings of nine panels each. Each string is connected to a separate MPPT DC input on one of the Sunny Boy inverters. So there is a total of 2 x 2700W (or 5.4kW) feeding each 4000W Sunny Boy inverter. Each panel has a maximum open-circuit voltage of 39.5V and a short circuit current of 10A. Maximum power output of each panel is 300W: 32.0V X 9.42A (NB: in a practical system solar panels are never operated open-circuit or short circuit).

Batteries & battery charging

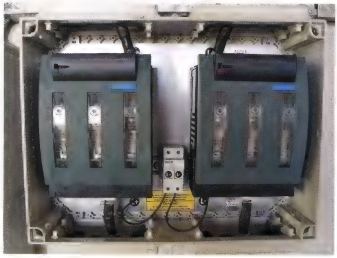
The battery bank consists of 24 Sonnenschein 2V 1959Ah (C_{120}) lead-acid cells connected to give a nominal 48V. The 48V battery is charged by an SMA "Sunny Island" SI8.0H Inverter/Charger (presumably, it is so named because it can be used in off-grid or "island" systems). It provides bi-directional energy conversion between the 48V battery bank and 230VAC. The battery bank may be either lead-acid or lithium ion, but in this case a lead-acid battery is being used.

For lead-acid batteries, the charger provides 3-stage charging, ie, initial bulk current charging, followed by a constant voltage phase and then a float charge phase. Every 14 days, there is a 2-hour boost charge and full equalisation charging is performed every 90 days, for a duration of 12 hours. The charging algorithm is quite complex and has been optimised to maintain the battery's state of health over multiple charge/discharge cycles. Output from the charger is 6kW.

The operation of the Sunny Island inverter is critical to the overall operation of the system. It can operate as a grid-tied inverter or stand-alone. When tied to the grid, it works in a similar manner to a grid-tied PV inverter, ie, it is synchronised to the grid and can export energy from the

Two screens taken from the Sunny Portal which show real-time data from Geoff's solar installation. The data was read on quite low usage days. Basically, green means power being generated on-site by the 45 solar panels – the screen at left showing 7.88kW – and also energy consumption. Red, on the other hand, shows energy being supplied from the grid – 2.06kW on the left screen, which would cost between 16 and ~60c per hour, depending on time of day. The screen above is even better, with just 0.06kW (maybe half a cent's worth!) being purchased. Compare these with the screen grabs overleaf.

The Sunny SRC20 Remote Control allows the system to be monitored and controlled remotely – a definite advantage on mid-winter nights in Yass! The four-line display gives current system status at a glance, and a memory card can be inserted to store all data.



These are the battery fuses and DC disconnect unit. In this installation, it has redundant fuses as it is designed to support three Sunny Islands, as would be used in a 3-phase system.

batteries to either the household loads or the grid.

Presently, in Geoff's system, the battery is only used to supply the home needs but there is now the possibility of the "grid export" feature, whereby the local grid operator can remotely control the operation of the Sunny Island inverter and instruct it to export to the grid at periods of peak demand (obviously, the system owner will get paid appropriately for this feed in.)

If the system detects grid failure, then the Sunny Island inverter/charger reverts to stand-alone or "island" operation, and provides a 230VAC reference to which the PV Inverters can synchronise and thereby supply the household load. At the same time, the batteries can be charged if sufficient solar power is available.

Both the three Sunny Boy PV inverters and the Sunny Island Inverter/Charger all have serial data ports, allowing energy flows and battery state of charge to be measured. Critical to system operation, the output voltage of the Sunny Island inverter can also be controlled, so that its contribution to the system output power can be set.

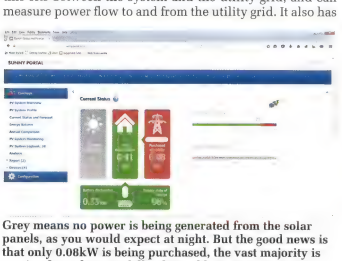
There is a smart meter which has "time-of-day" tariff and this sits between the system and the utility grid, and can measure power flow to and from the utility grid. It also has a serial (modified Ethernet) data output. Finally there is the Sunny Home Manager, effectively the control computer that looks after all the energy flows in the system.

It does this by adjusting the output voltages (and thus power) of the PV Inverters and the inverter in the Inverter/Charger. It also reports lots of system information to the internet for remote analysis and viewing by the system owner (in this case, Geoff Woodman).

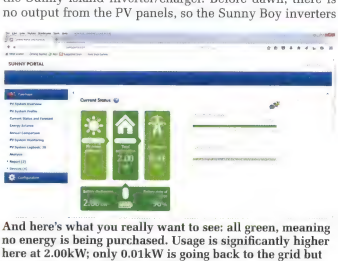
There is also an Automatic Transfer Switch (ATS) which contains a contactor to isolate the system from the utility grid in the event of a grid failure, so it can run "stand alone" as an island grid. This does not provide instantaneous changeover in the case of a blackout because many of these are very short, often <1s. Instead, there is a delay of about five seconds between the grid going down, the contactor isolating the grid and then the Sunny Island powering up to provide 230VAC from the battery bank.

Daily operation

So let's consider a typical day: The house has been running off the batteries overnight, with 230VAC generated by the Sunny Island inverter/charger. Before dawn, there is no output from the PV panels, so the Sunny Boy inverters



Grey means no power is being generated from the solar panels, as you would expect at night. But the good news is that only 0.08kW is being purchased, the vast majority is coming from the near-fully-charged battery bank.



And here's what you really want to see: all green, meaning no energy is being purchased. Usage is significantly higher here at 2.00kW; only 0.01kW is going back to the grid but at least it is going in the right direction!

are asleep. The Sunny Island inverter/charger is locked to the utility grid and its output voltage has been adjusted so that it is supplying all the power to the household loads, but no export to the grid.

It does this by constantly adjusting its output to be identical to the utility grid voltage, so there is no power flow in either direction through the SMA smart power meter. At sunrise, the batteries are discharged (say) 20%, and are thus at 80% State of Charge (SOC).

After sunrise, assuming a cloudless sky, the PV panels start producing power, and the Sunny Boy inverters wake up and synchronise to the utility grid. As they start producing power, their output voltages are adjusted to match the utility grid voltage, so that all the power they produce flows to the household loads; there is no power to or from the grid at this time.

As the output of the Sunny Boy inverters rises with increasing output from the PV panels, the power drawn from the batteries decreases, as the household loads are supplied more and more from the increasing output from the PV panels. Then, as the output of the Sunny Boy inverters continues to increase through the morning, the Sunny Island switches its mode and starts charging the batteries. The Sunny Home Manager continuously adjusts the output voltages of the Sunny Boy inverters so there is no power feed to/from the utility grid.

All the solar generated power excess to household consumption is used to charge the batteries. When the output of the Sunny Boy inverters rises above the total household demand and the maximum that can be used for battery charging (6kW), the output voltage is adjusted so that excess solar generated power is fed into the utility grid. If the output of the PV inverters exceeds the sum of the battery charging requirements, household loads and permissible grid-feed of 2.5kW, the Sunny Home Manager reduces the AC voltage output of the PV inverters to keep the grid-feed limit to its permitted maximum.

The Sunny Portal doesn't just give statistics – it can give forecasts and recommended actions, as seen in the graph at the bottom of the screen. Of particular interest on this mid-winter graph is that it is forecasting *some* solar energy generation even after 5pm, contrary to popular belief which says you won't get anything after about 4pm.

Grid Connected, Off-Grid AND Hybrid

Many people are confused about the different types of solar power installations which you can install.

GRID CONNECTED: as its name suggests, you are always connected to the electricity grid and when it goes down, so does your supply. You do not normally have any batteries to charge because any excess power you generate from your system is usually sold back to the electricity supplier. However, in new installations the amount paid is much less than what they charge you – typically, about 6c to 8c per kWh (they charge you as much as 50c per kWh!) The vast majority of domestic solar power installations are grid connected.

OFF GRID: again, as its name suggests, you are not connected to the electricity grid at all. This is sometimes referred to as "islanding". Your system will normally have a bank of batteries which are charged by the solar panels and you take power from the batteries, invert it to 230VAC mains, and use it to power your home. If you generate more power than you can use or to charge your batteries, it is normally wasted. Off Grid installations have been popular if you are a long way from the power lines.

HYBRID: this is a mix of the two – you remain connected to the grid but your solar panels generate enough power to run your home and to charge batteries. If the grid goes down (a "blackout"), your system will switch over and you will have power even if everyone else is in darkness! If you generate more than you can use or to charge your batteries, it can be sold back to the utility. However, like grid-connected, the price they pay you is very small compared to what they charge you for the same power. The other major disadvantage is that you will continue to pay the electricity "availability" charge, even if you never actually use any power from the grid.

As the day progresses, the output of the solar system peaks and then begins to decline. Grid-feed is progressively reduced, household loads are supplied as a priority and any excess is used to float charge the batteries. When the output of the PV system falls below the household load requirement, the Sunny Island switches to "inverter" mode and starts drawing the "shortfall" power (ie, the difference between the PV generated power and the household demand) from the batteries. As the sun sets and/or the output of the solar panels falls, the proportion of the household power supplied by the Sunny Island inverter/charger continues to increase until it reaches 100%, and thus is all coming out of the batteries (up to the power limit of the Sunny Island inverter).

If it has been a heavy overcast day, with reduced output from the solar panels, the batteries may receive little or no charge. If this is the case, the batteries will continue to supply the household loads via the Sunny Island inverter/charger.

When the battery SOC decreases to 65% (or whatever the limit has been set to) the inverter is effectively switched off and the household load is supplied directly from the utility grid.

When power from the solar panels is again available, it will first supply the household loads (decreasing the power drawn from the utility grid), and then begin charging the batteries as/when there is sufficient output to do both. The 65% SOC lower limit has been set to ensure a cycle life of 4,500 cycles for the lead acid batteries in Geoff's system.

Lithium ion batteries in some hybrid systems are routinely discharged to 20% SOC for a similar life cycle.

Installation

18 of the 54 solar panels in this installation are mounted on each side of a large shed's hip roof (ie, 36 in total) while the remaining 18 are on a relatively flat skillion roof. The panels are then grouped and fed to the three Sunny Boy inverters to more-or-less equally share the load across all the panels, although some panels will be generating larger amounts during the day, depending on their orientation and the sun's position in the sky.

The fact that the total panel capacity is about 30% higher than the Sunny Boy inverters can actually fully use (see above) means that there should be plenty of generating capacity even on light overcast days.

All of the inverters, circuit breakers, the Sunny Home manager, smart power meter and other gear is mounted on the back wall of a section of the shed which is also used to garage a car (with suitable barriers in front of the inverter gear to stop the unthinkable collision of a car with all that expensive electronics).

The large battery bank is accommodated in another section of the shed, with plenty of space around it.

Geoff can check the overall operation of the entire system at any time by logging into his individual pages at www.sunnyportal.com

All of the screen grabs in this article were taken from that site as this article was prepared in late August. Note that this was during a succession of cloudy days so I did not see the solar panels and Sunny Boy inverters generating their maximum capacity of 12kW. The typical maximum during this period was around 9.5kW, possibly because the total demand meant the Sunny Home Manager had limited the output of the Sunny Boys.

Geoff can also check the operation of the three Sunny Boy 4kW inverters via their LCD panels, which show the output of the panels connected to each MPPT input.

Overall, the system is very impressive in its engineering. The overall domestic load is probably somewhat higher than you might expect because all heating and cooling in the home is via reverse cycle air-conditioning.

At normal ambient temperatures RC air-conditioning is very efficient as a heat pump but once the outside air temperature drops below 5°C, it becomes quite inefficient and arguably no better for household heating than electric radiators; perhaps even less so.

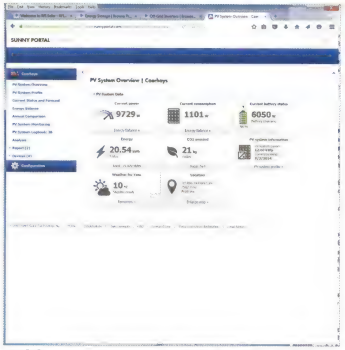
Investment & return

This is a far bigger and much more expensive system than the typical "domestic" grid-tied solar system with no storage, which currently are routinely advertised at about $5,000-$20,000, depending on size. The 24 storage batteries alone would leave little change out of $50,000.

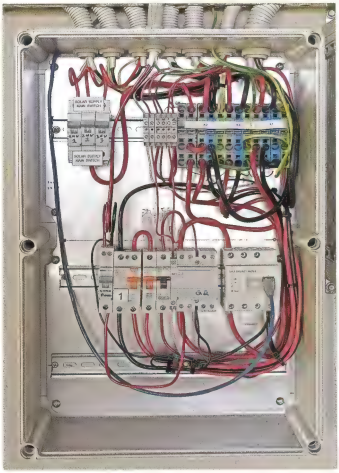
In the first 12 months of operation, the system was 84% self-sufficient. Of the 16% bought from the grid, 12% was at off-peak rates (16c/kWh) and the remaining 4% at peak and/or shoulder rate (30c/kWh).

Allowing for the $10,000 rebate from Renewable Energy Certificates (RECs), the total investment in the system has been about $70,000. Geoff calculates that, in a year of operation, he has saved about $5000 in his energy bills. That is a yield of about 7%. But if you consider that yield is free of income tax, an equivalent "before tax" yield could be above 12%. With those points in mind, the payback period in today's dollars is about eight years, without factoring in

Just as important in a solar power installation, the Sunny Portal also gives you historical data of power generation, purchased power, grid feed in and your own consumption; everything from the last few minutes to the last year. This data can help users modify their energy consumption to achieve maximum efficiency with their installation.



And there's even more data available should you wish to take advantage of it: this Sunny Portal screen shows the current power (9729W), the current consumption (1101W), energy used today (20.54kWh), CO_2 avoided (21kg), the solar panel power (12.60kWp) and its commissioning date; even the local weather and the installation location.



The ATS contactor (labelled Q2) which senses, and disconnects the grid in case of dropout. Alongside is an SMA energy meter (bottom right). A data port connects to the Sunny Home Manager.

any inevitable increase in energy tariffs.

Some readers may question why there are so many solar panels in the installation. This was a judgment based on the figures from Climate Data Online on the Bureau of Meteorology website, which give the average June insolation in Yass as 2.0kWh/m^2. This varies from year to year, but typical daily minimums are about 0.9kWh/m^2 and maximums are about 3.0kWh/m^2.

Also, there is restricted north facing roof space so Geoff chose to mount the panels on a low-pitched roof that faces east and west. Because of the low pitch, the output of the panels is basically the same as if they were lying flat, ie, 16.2kW x 2.0 = 32.4kWh on an average day; 16.2 x 0.9 = 14.6kWh on a poor day and 16.2 x 3.0 = 48.6kWh on a good day.

Daily consumption in June 2015 averaged 29.9kWh, mostly due to house heating with the reverse-cycle air conditioning. This means that, on an average day, the yield from the panels is only just greater than the average demand.

If you factor in the losses involved in charging and discharging the batteries, there isn't enough PV on an average June day to make the system grid independent.

The output of the panels in summer is, in fact, higher than if they were facing north, so the system has a high degree of autonomy over the summer months and a high export factor to the grid. SC

Australian concept Electric Vehicle runs on its own solar panels

by Ross Tester

IMMORTUS

Imagine driving an electric vehicle which NEVER requires plugging in – all its power for normal operation can come from roof and bonnet-mounted solar panels. If a Melbourne start-up turns its "Immortus" concept into a production vehicle, that's exactly what will happen.

If you've ever scanned the comments section on an electric car or bike article, you'll be familiar with this complaint: "that's not green, it's just a coal-powered vehicle." The detractors are, of course, referring to the fact that an EV's power had to be generated somewhere, for example a coal-fired power station. They are completely ignoring the fact that many EV owners generate their own power (solar) or even pay extra to have "green" power (hydro, wind etc).

Well, they can't denigrate the Immortus.

While still a "concept" EV car (ie, none have actually been built yet, let alone sold!), it has been designed to generate either 100%, or the vast majority (depending how it is driven), of its own power through some seven square metres of solar photovoltaic paneling mounted on its roof and bonnet.

You *can* charge its battery off the mains if you have to but if conditions are sunny, the inbuilt solar panels alone will let you drive at more than 60km/h for an unlimited distance.

Solar racing heritage

The Immortus technology is based on solar racecars, which are powered solely by what they can generate from their solar cells as they drive along (ie, no plug-in power or even generators allowed). The project was originally founded by Australia's Aurora Solar Car Team, which has competed in a bunch of solar race events across the world.

Hence the light weight and the shape of the Immortus, which combines maximal sun exposure with extreme aerodynamics, including covered wheels.

Unlike the solar racers, though, the two-seater Immortus is designed to approach practicality on the road, with a 0-100km/h time that will be less than seven seconds and a top speed over 150km/h. It also has a modest luggage capacity for daily driving.

Melbourne-based EVX Ventures, creators of the Immortus, even list fun as a priority, saying it should handle like a well-balanced sports car.

Squeezing unlimited range from solar energy

Where the Tesla Model S has a massive 85kWh battery pack, the self-charging system on the Immortus uses only a 10kWh lithium-iron-phosphate battery. The car uses twin DC motors mounted on the uprights leading to each rear wheel hub, each with a peak output of 20kW, for a total peak output of 40kW (53.6 hp). While 40kW doesn't sound like much, the entire car has been designed to make the most of its power. A feather-light weight of around 550 kg (1,212 lb) gives the Immortus a power-to-weight ratio and acceleration time similar to a Mazda MX5 (aka Miata) and the weight distribution is designed to offer similarly sporty handling characteristics.

The Mazda will out-corner it though, because the Immortus won't use regular road tyres. It will use tyres specifically designed for solar racers; very thin wheels with low-friction tyres that prioritise low rolling resistance over grip. These aren't the most attractive wheels but then they're hidden away behind the aerodynamic wheel arch covers anyway.

Thanks to exceptionally low weight, low-drag aerodynamics, EVX expects the car's small 10kWh battery pack to be good for just under 400km of range even at night, when there's no solar assistance top-

ping it up. When the sun is out and the road is clear, that range goes up, effectively to infinity if you stay around 60km/h. Upping the pace to 85km/h the range drops to about 550km.

Distributed manufacturing – every car a custom

Ease of construction is key for the Immortus team, because they don't plan to mass-produce the car, or even to build it in-house.

"We're not trying to be a Tesla," says Barry Nguyen, CEO and co-founder of EVX Ventures. "Tesla is a mass manufacturer of cars, we're designers of boutique custom electric cars and aftermarket products. There are regulations in the US and Australia that allow for individually constructed vehicles. Essentially what that means is that if you contract a custom car builder with the designs and components, you can build a road-legal car without the crash testing and the 5-10 million dollars you'd have to raise to do that. We plan to sell those cars in low volume."

Thus, the Immortus has been designed to be exceptionally simple to assemble. Abandoning early concepts that used a carbon-fibre monocoque frame with two large tubs, the most recent design features an ultra-lightweight space frame using off-the-shelf carbon fibre tubing, with 3D-printed nodes to connect the tubes. The frame of the car is effectively like a big Meccano set.

"This simplifies the manufacturing process, as well as reducing transport costs," says technical lead Clint Steele. "The plan is to have these cars assembled by custom car builders close to wherever the customer is. The custom shops can source their own carbon fibre tubing and we can either send over the 3D-printed node parts or send over the designs so they can print them locally."

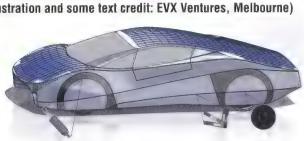
Got a lazy half-million?

EVX doesn't expect to sell more than 100 of the Immortus. At an estimated AU$500,000 (approx. US$370,000) depending on spec, it's a boutique, high priced technology platform that will only appeal to extremely wealthy early adopters. But the ideas developed through the Immortus project are filtering out into a range of other projects that are much more consumer focused. EVX is looking to raise about US$1.5 million to get the Immortus production ready, and will be taking a scaled-down, remote control version of the Immortus to this month's (October) SEMA exhibition in Las Vegas.

EVX is still trying to decide whether to remain in Melbourne or to move to California. "Melbourne is home," they say, "but California has a lot more high-worth early-adopters, the kind of people who might take a half-million chance on an unproven solar car."

Either way, early as it is, the Immortus, along with the Stella Lux prototype from the Netherlands, paves the way for a new category of vehicle, one that's all but energy independent. An electric car in which you rarely, if ever, have to think about where the next charge point is; a high-end, high tech sportscar you won't want to keep in your garage, because it can't get any sun in there. And as battery technology and photovoltaic efficiency continue to improve, these kinds of cars could become a lot more viable. SC

(Illustration and some text credit: EVX Ventures, Melbourne)



It's not just the solar panels which make this car unique: even the shock absorbers are designed to produce power!

Think this is all "Pie-in-the-sky" stuff?

Pictured above is the "Sunswift V (or eVe)", the University of New South Wales award-winning entrant in the World Solar Challenge (WSC) race from Adelaide (SA) to Darwin (NT). That this vehicle holds a number of world records, including the Guinness World Record for the fastest solar-powered vehicle is significant enough. However for this story, what is even more significant is that this vehicle is the first in Australia – and one of very few in the world – which is road legal; that is, it passes the strict Australian Design Rules (ADRs) which means it can be registered and used on Australian roads.

World Solar Challenge entrants have all run under special provisions, meaning vehicles incapable of "normal" operation were permitted to run the race.

In fact, earlier WSC racers have been anything but road legal; more somewhat flimsy and unstable mobile platforms on which solar cells are mounted! (See the photo of the 2013 Adventure class winner, the Aurora Evolution, on which the Immortus technology is loosely based).

Drivers of the earlier racers reported the dread of seeing a road train approaching – in fact, there were at least a few accidents as the buffeting of very fast-moving road trains and even caravans took their toll on the lightweight race cars. The wing-shape didn't help at all!

Even so, the times achieved by the solar-powered racers, moving from the first rays of sunlight in the morning, to just before dusk (rules dictated when the cars could move) were quite impressive: the Aurora Evolution achieved first place in 38 hours and 39 minutes driving time – some 3022km – at an average speed of 77.5km/h.

Ultra-LD Mk.4 Power Amplifier Module, Pt.3

110W version plus power supply details

• 2.4dB less power • Same excellent performance figures • Less expensive

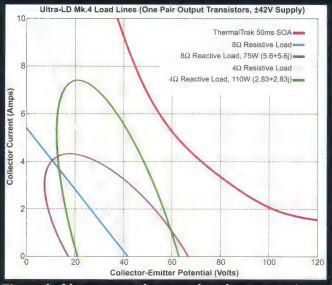


Fig.11: the blue, green and mauve plots show current/voltage curves for resistive and reactive loads with 8-ohm & 4-ohm impedances driven with a sinewave at 75W and 110W respectively. Voltages are calculated for ±42V supply rails with an infinitely large capacitor bank. The red curve is the 50ms safe operating area for the NJL3281D & NJL1302D ThermalTrak output transistors. This shows that the transistors should not be damaged by driving such loads with an audio-frequency AC signal.

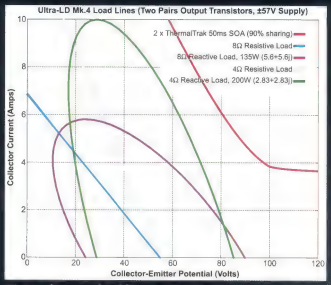


Fig.12: the same load lines and safe operating area curves as for Fig.11 but this time for the higher ±57V supply rails and full power ratings of 135W into 8Ω and 200W into 4Ω. They are well within the safe operating area which has been moved up vertically to allow for the fact that the full-power version of the amplifier uses the output transistors in pairs. Note that we published a similar graph in the July 2011 issue however these plots are more accurate.

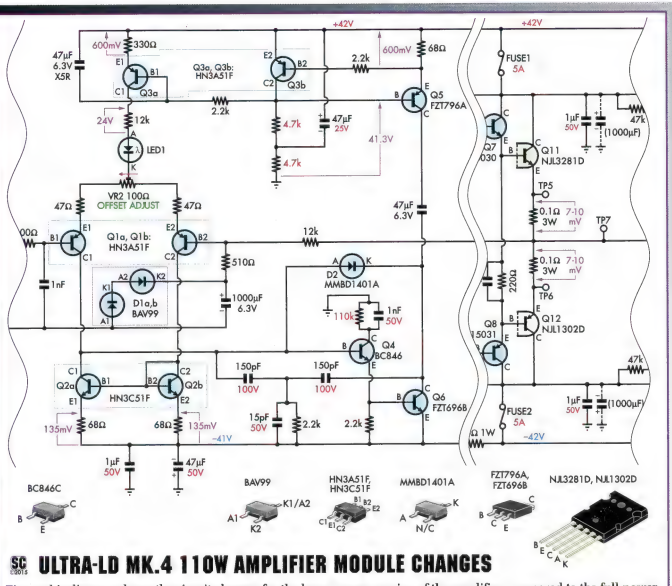
Last month, we described how to build the new high-performance Ultra-LD Mk.4 amplifier module. Here are the details for the lower-power version, so you can save money while still obtaining the same ultra-low distortion and signal-to-noise ratio. We'll also get into building the power supply plus testing and setting up both versions of the module.

By Nicholas Vinen

IF YOU'RE going to use the Ultra-LD Mk.4 to drive very sensitive speakers such as our Majestic (June & September 2014) or Senator (September & October 2015) designs, the full 135W into 8Ω is far more power than you'll actually need for home listening. To save some time and money, you can build a lower power version which produces up to 75W into 8-ohm loads and 110W into 4-ohm loads, with a music power rating of around 85W into 8 ohms and 140W into 4 ohms.

Its distortion and noise performance is very similar to the full-power module. For many people, the lower power version will have all the power and performance that they are ever likely to want.

In fact, the power difference between the full and lower power versions of this amplifier is only 2.4dB; most people will never notice the difference!



ULTRA-LD MK.4 110W AMPLIFIER MODULE CHANGES

Fig.13: this diagram shows the circuit changes for the lower power version of the amplifier, compared to the full-power circuit shown in the August 2015 issue (pages 34 & 35). Differing component values and ratings are shown in red. The main changes are the removal of one pair of output transistors, changes in the feedback resistor value, lower current fuses, a reduced value current limiting resistor for Q4/Q6 and lower voltage ratings for many of the capacitors.

The main cost saving with the lower-power module is in the transformer, as a 160VA toroidal type is used instead of the 300VA type for the higher power version. You also save the cost of two power transistors per module, can use a smaller (and thus cheaper) heatsink and can also omit a few other passive components.

Fig.11 shows resistive and reactive (ie, simulated speaker) load lines for 75W into 8Ω and 110W into 4Ω compared to the safe operating area (SOA) of one pair of ThermalTrak output transistors. As you can see, there is adequate margin of safety. The 50ms safe operating area was chosen based on a typical minimum operating frequency of 20Hz, although given that the limit is mainly at the peaks, this is sufficient even for lower frequency (inaudible) signals, should they be present in a recording.

Compare this to Fig.12 which shows the same curves for the module using two pairs of output transistors at its full rated power of 135W into an 8-ohm load and 200W into a 4-ohm load.

Circuit & PCB changes

The changes to the circuit are shown in red on Fig.13. The most obvious change is the omission of one pair of output transistors and their associated emitter resistors. We chose to omit the outer pair in our prototype, mainly as this allows for the use of a smaller heatsink.

The mains transformer changes from a 40V-0-40V 300VA type to 30V-0-30V 160VA type, producing supply rails of nominally ±42V. These lower supply rails mean that many of the capacitors in the circuit can be lower voltage types which are a little easier to obtain and cheaper too.

A few other component values in the amplifier module need to be changed. The two series 6.2kΩ resistors at Q3b's collector drop to 4.7kΩ to keep its operating current the same.

Importantly, the 150kΩ current-limiting resistor for the VAS (Q4/Q6) must be reduced in value to 110kΩ, to

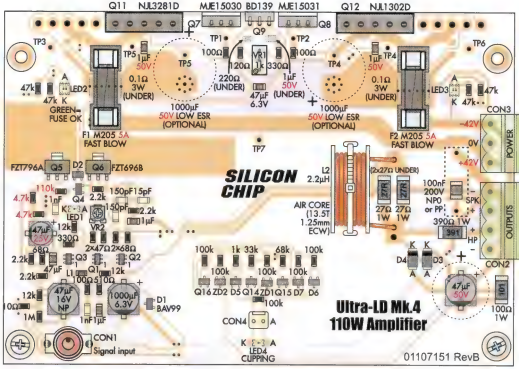
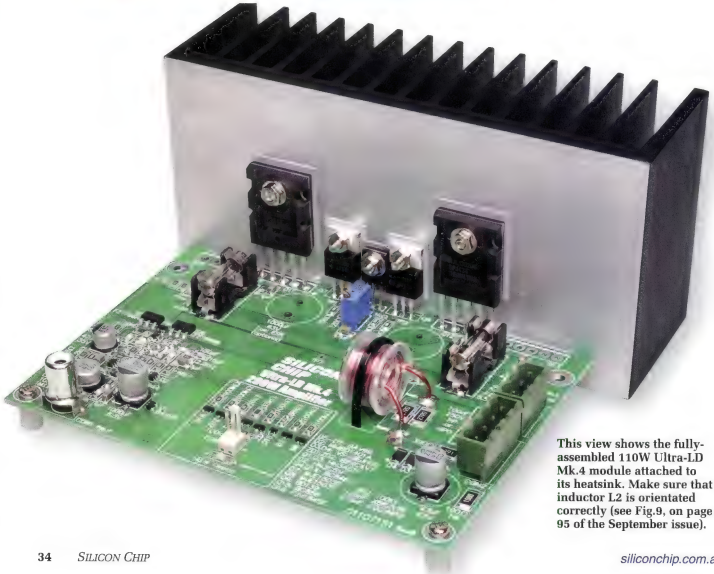


Fig.14: use this diagram, along with the instructions in the article last month, to build the lower power version of the amplifier. The changed component values are shown in red. You may of course use capacitors with the original (higher) voltage ratings if desired. The only components left off the top side of the board are the outer pair of output transistors, Q10 and Q13.



This view shows the fully-assembled 110W Ultra-LD Mk.4 module attached to its heatsink. Make sure that inductor L2 is orientated correctly (see Fig.9, on page 95 of the September issue).

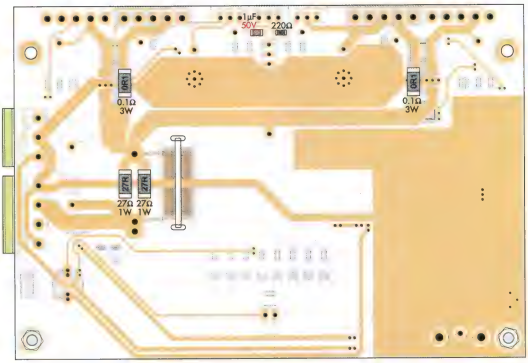


Fig.15: the only changes to the components on the bottom side of the PCB for the lower power version are the omission of two of the 0.1Ω emitter resistors and the lower voltage rating on the 1µF capacitor.

allow sufficient current for Q6 to pull the output low while still protecting it from excessive dissipation in a fault condition. We've also dropped the fuse ratings slightly, as the unit will draw less current from the power supply and a number of capacitors are rated at 50V (down from 63V/100V) or 100V (down from 200V).

Construction

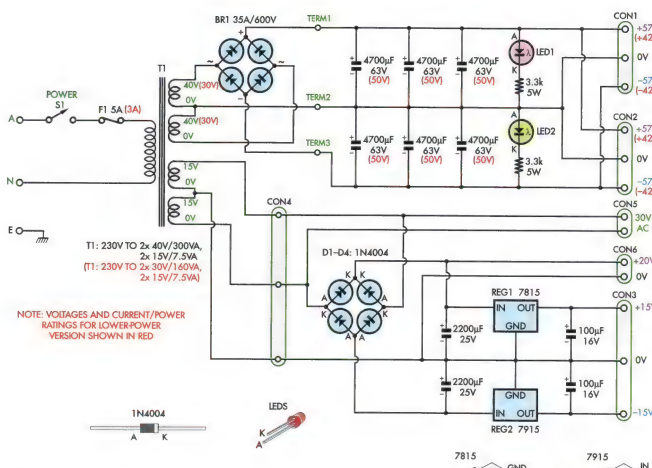
Construction is the same as for the full-power module presented last month, except for the aforementioned changes. Use the overlay diagrams of Fig.14 and Fig.15 as a guide. As with the circuit, the changes are shown in red but note also that the two output transistors and their associated emitter resistors and bypass capacitors are all omitted entirely.

Note that when the PCB is mounted on the smaller heatsink, it is not centred but is offset to the left. This has been done so that the transistor mounting screws fit between the fins of the heatsink. If you want to have the PCB mounted on the exact centre of the heatsink, the various screw holes will need to be blind-tapped from the front. The heatsink drilling diagram is shown in Fig.17.

Power supply

The complete power supply cir-

Six parts are fitted to the underside of the PCB for the 110W version – five SMD resistors and one SMD capacitor. Note that the two 0.1Ω resistors must be rated at 3W, while the 27Ω resistors must be rated at 1W. The 220Ω resistor at the top of the board (adjacent to the heatsink) is rated at 0.5W and is a thin-film type (see parts list on page 38 of the August 2015 issue).



ULTRA-LD AMPLIFIER MK POWER SUPPLY

Fig.16: the Ultra-LD Mk.4 power supply circuit is identical to that used for the Ultra-LD Mk.3. The changes necessary for the lower power version are shown in red. Power switch S1, fuse F1, transformer T1 and bridge rectifier BR1 are mounted on the chassis, while the rest of the parts are mounted on the power supply PCB.

cuit diagram is shown in Fig.16. It is suitable for driving either one or two modules with normal program signal sources such as a CD player, FM/DAB tuner etc. The maximum continuous output power will be lower than specified when driving two modules from one transformer and power supply PCB but with normal program material this will still be more than adequate; the music power rating will only drop slightly when two modules share the same power supply.

The power supply for the Ultra-LD Mk.4 is essentially identical to that used for the Mk.2 and Mk.3 versions. Various voltages differ for the lower power version and these are noted in square brackets in the following text.

The supply is based on a toroidal mains transformer (T1) with two 40V [30V] windings and two 15V windings. The two 40V [30V] windings are connected together to give 80VAC [60VAC] centre-tapped and this arrangement drives bridge rectifier BR1. This in turn feeds six 4700µF 63V [50V] electrolytic capacitors (ie, 14,100µF on each side) to provide balanced ±57V [±42V] DC (nominal) rails to power the amplifier.

Two LEDs are connected in series with 3.3kΩ 5W current-limiting resistors across these ±57V [±42V] supply rails. These serve two purposes: (1) they provide a handy indication that power is present on the supply rails (or when it is not present) and (2) they discharge the filter capacitors when the power is switched off (see warning panel).

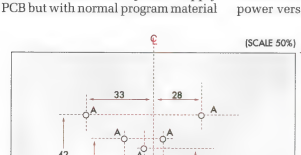


Fig.17: this half-size diagram shows the heatsink drilling details. The holes can either be drilled and tapped (using a 2.5mm drill and M3 tap) or can be drilled to 3mm and the transistors mounted using machine screws, nuts & washers.

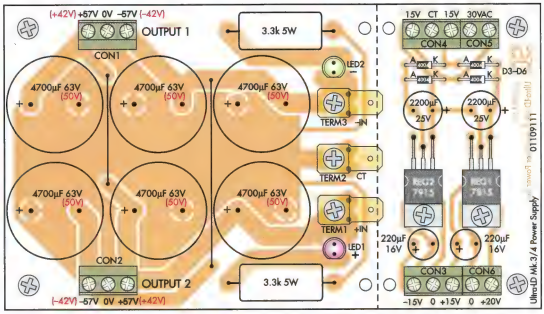
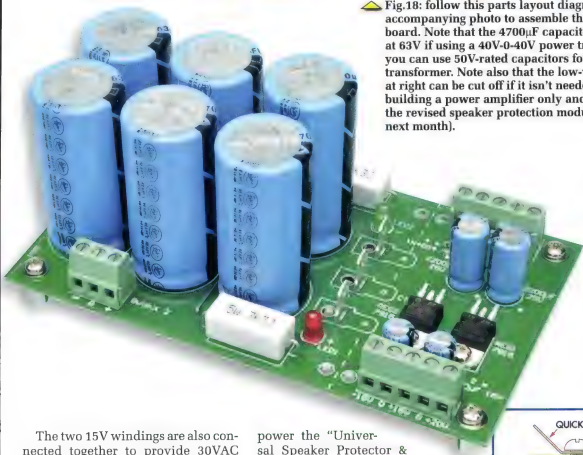


Fig.18: follow this parts layout diagram and the accompanying photo to assemble the power supply board. Note that the 4700µF capacitors must be rated at 63V if using a 40V-0-40V power transformer but you can use 50V-rated capacitors for a 30V-0-30V transformer. Note also that the low-voltage section at right can be cut off if it isn't needed (eg, if you are building a power amplifier only and you intend using the revised speaker protection module to be described next month).



The two 15V windings are also connected together to provide 30VAC centre-tapped. These drive bridge rectifier D1-D4 and two 2200µF filter capacitors to derive unregulated rails of about ±20V. These rails are then fed to 3-terminal regulators REG1 & REG2 to derive regulated ±15V supply rails to power a preamplifier module.

The +20V rail is also made available as an output, along with a 30VAC output. The +20V rail can be used to power the "Universal Speaker Protector & Muting Module" described in the October 2011 issue, while the 30VAC output is connected to the "AC Sense" input of this module. This latter input is used to quickly disconnect the speaker when the power goes off, to avoid switch-off thumps.

Updated speaker protector

We intend to describe an updated

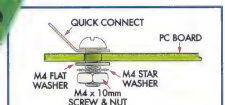


Fig.19: if you can't get the through-hole spade lugs or prefer to use the screw-mounting types, here's how to attach them to the PCB. The power supply board has provision to use either type.

Parts List Changes For 110W Version

Add these parts to the Ultra-LD parts list in August 2015

1 black anodised aluminium heatsink, 150 x 75 x 46mm (L x H x D)
2 5A M205 fast-blow fuses (F1, F2)

Capacitors (add)

1 47µF 50V SMD (8mm) or through-hole electrolytic capacitor (eg, Digi-Key 493-9427-1-ND)
1 47µF 25V SMD electrolytic, 6mm diameter (Digi-Key 493-9423-1-ND)
5 1µF 50V X7R (Digi-Key 1276-1068-1-ND)
2 1nF 50V NP0/C0G (Digi-Key 311-1122-1-ND)
2 150pF 100V NP0/C0G (Digi-Key 311-1839-1-ND)
1 15pF 50V NP0/C0G (Digi-Key 1276-1163-1-ND)

Resistors (0.5W 1% Thin Film, 3216/1206) (add)

2 4.7kΩ or 4.75kΩ (Digi-Key RNCP1206FTD4K75CT-ND)

Resistors (other) (add)

1 110kΩ 0.25W 1% 3216/1206 SMD

Delete these parts from the Ultra-LD parts list in August 2015

1 black anodised aluminium heatsink, 200 x 75 x 45mm (L x H x D)
2 6.5A M205 fast-blow fuses (F1, F2)
2 TO-264 or TOP-3 silicone insulating washers

Semiconductors (delete)

1 NJL3281D* NPN ThermalTrak transistor, TO264-5
1 NJL1302D* PNP ThermalTrak transistor, TO264-5

Capacitors (delete)

1 47µF 63V SMD (8mm) or through-hole electrolytic capacitor (eg, Digi-Key 493-6401-1-ND)
1 47µF 35V SMD electrolytic, 6mm diameter (Digi-Key 493-9433-1-ND)
7 1µF 100V X7R (Digi-Key 1276-2747-1-ND)
2 1nF 100V NP0/C0G (Digi-Key 445-5759-1-ND)
2 150pF 200V NP0/C0G (Digi-Key 399-9174-1-ND)
1 15pF 100V NP0/C0G (Digi-Key 311-1838-1-ND)

Resistors (0.5W 1% Thin Film, 3216/1206) (delete)

2 6.2kΩ or 6.49kΩ (Digi-Key RNCP1206FTD6K49CT-ND)

Resistors (other) (delete)

1 150kΩ 0.25W 1% 3216/1206 SMD
2 0.1Ω 3W 1% Metal Film/Element (Digi-Key CRA2512-FZ-R100ELF)

version of the Universal Speaker Protector next month, specifically to suit the Ultra-LD Mk.4. Like the amplifier module, this will mainly use SMDs and adds a number of extra features such as indicator LEDs, simplified chassis wiring, NTC thermistors for easier temperature monitoring, the ability to drive a cooling fan if the amplifier reaches a certain temperature and more.

Unlike the previous version, the updated speaker protector does not require a +20V rail; it can use the same transformer output for AC sensing and to power itself. In fact, it will even work from the same transformer windings that run the amplifier modules if your transformer lacks a 30VAC output. However, you can still use the October 2011 speaker protector with the Ultra-LD Mk.4 if you wish; this is currently available as an Altronics kit (K5167).

Power supply assembly

Fig.18 shows the parts layout on the power supply PCB, which is coded 01109111. You can either purchase the PCB from the Silicon Chip Online shop or you can buy a complete kit of the power supply from Altronics, Cat. K5168.

Begin by fitting the two wire links using 0.71mm or 1mm-diameter tinned copper wire (1mm diameter is better but you may need to enlarge the holes slightly). If you bought the PCB from us, it will be double-sided so no wire links will be necessary.

If you don't need the low voltage regulated outputs, you can simply cut the PCB along the dotted line and discard the unwanted section. In this case, skip the instructions to install the components on that part of the board. It's also possible to keep this part of the board and mount it separately, should your application require that.

Assuming you do want the low voltage outputs, fit the four 1N4004 diodes (D1-D4), orientating them as shown. Then install the two 3-terminal regulators. You will need to bend their leads down by 90° so that they fit the PCB pads with the tab mounting hole lined up correctly. Attach each regulator to the board using an M3 x 6mm machine screw, shakeproof washer and nut, taking care not to get the two different types mixed up. Solder the leads after the screws have been tightened.

The two LEDs can go in next. These sit flush against the PCB with the flat side of the lenses orientated as shown on the overlay. Follow these with the two 3.3kΩ 5W resistors. These should be stood off the board by about 2mm, to allow the air to circulate beneath them for cooling (use a cardboard spacer during soldering).

The two 5-way screw-terminal connectors are made by dovetailing 2-way and 3-way blocks together. Be sure to fit these assemblies with the wire entry holes facing towards the adjacent edge of the PCB.

The two 3-way terminal blocks for the ±57V (or ±42V) outputs can then go in. Alternatively, instead of fitting these blocks, you can solder the DC supply leads directly to the PCB pads if it will be mounted right next to the amplifier modules.

The three Quick-Connect (spade) terminals are next. If you are using PCB-mount connectors, simply push the pins through and solder them in place. It will take a while to heat the connectors so that the solder will "take". However, be careful not to overdo it, as the solder could "wick" through the hole and onto the spade section.

If you are using 45° chassis spade lugs instead, screw them down tightly using M4 machine screws, nuts and washers – see Fig.19. If you can't get single-ended chassis lugs, cut one side off double-sided lugs.

Finally, fit the electrolytic capacitors, starting with the two 220µF units and finishing with the six large 4700µF units. Be sure to orientate them correctly and make sure that they all sit flush against the PCB.

If you are building the lower power version, you may have to crank out

the 4700µF capacitor leads to suit the board (or stick with the 63V versions). In this case, it would also be a good idea to apply a little neutral-cure silicone sealant around the base of the capacitors so that they aren't supported by the leads alone.

Cabling

The plug-in terminal block connectors on the power amplifier modules make installing and removing them much easier than before. Note that it's important to use the thickest wire you can easily fit into the terminal blocks and to keep the wiring as short and as tight as possible. This is especially important if you opted not to fit the electrolytic supply bypass capacitors on the amplifier modules.

Each set of three supply wires should be tightly coupled by twisting them together and/or covering the bundle with a length of heatshrink tubing (ideally both). Otherwise, the class-B currents flowing through the supply leads could couple into the amplifier module(s) and ruin the performance.

Be careful when inserting the wires into the 3-way terminal block that you get the polarity right. Fig.20 shows the wiring polarity so be sure to match this.

Initial testing

We've come up with a revised procedure for powering up the amplifier the first time, to greatly reduce the chance of damage to any components if there are problems. This involves initially connecting 68Ω safety resistors in series with the supply connections before powering it up.

The easiest way to do this is to insert one lead of a 68Ω 5W resistor into each of the two terminals at either end of the block and do the screws up tightly, then similarly screw the other ends into a 3-way mains terminal block. You can use insulated wire or a 0.1Ω 5W resistor for the ground connection – Fig.20.

The advantage of doing it this way is that you can easily calculate the current flowing through the resistors by monitoring the voltage across them with a DMM. The lead are also unlikely to short together, as long as they are carefully arranged initially.

The other side of the terminal block is wired to the DC outputs of the power supply. This will need to be built and wired up inside an earthed case. The simplest solution is to build the power supply into the case you intend to use for your final amplifier and then run an extra-long 3-way lead out of the case for testing purposes.

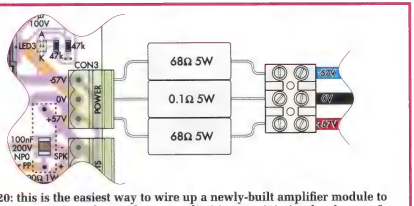


Fig.20: this is the easiest way to wire up a newly-built amplifier module to the power supply and provide current limiting to minimise the chance of damage if there is a fault. The 68Ω resistors limit the current flow to 600-800mA in the worst case. The 0.1Ω resistor is used simply for convenience; a short length of insulated wire could be used instead. Ideally, the voltage across both 68Ω resistors should be monitored initially. The expected current drain for a new module with the output stage bias set to minimum is less than 20mA, resulting in less than 1V across each safety resistor.

Don't skimp on this arrangement; make sure all the mains wiring is properly insulated and anchored for the tests. Once you have verified the module(s) are working you can then mount them in the case and complete the amplifier. Refer to the details on putting the power supply together later in this article (under the "Chassis Assembly" cross-heading).

For the time being, we'll assume that you already have a power supply (eg, if you built a previous version of the Ultra-LD amplifier). **If so, take a look now at the "Danger: High Voltages" warning panel on this page. The power supply generates high AC and DC voltages and high DC voltages are also present on the amplifier module.**

Before you plug the power supply connector into CON3 on the amplifier board, switch on the now complete power supply and verify that the voltages at its output terminals are correct. The exact DC voltages will vary depending on your mains supply but you should get something like 54-57V for the full power version or 39-42V for the low-power version. Be especially careful to check for the correct polarity.

Switch off and wait for the LEDs on the power supply board to go out before connecting the module. Then connect a DMM set to measure volts across each safety resistor using alligator clip leads. If you don't have two DMMs, just monitor one resistor. If you don't have alligator clip leads, you will have to hold the probes in place after switching power on.

Now wind VR1 fully anti-clockwise and set VR2 to its halfway position using a small jeweller's screwdriver. Ensure F1 and F2 have not been fitted, then switch the power on and check the on-board LEDs and the DMM readings. You should see LED1 (blue) on the amplifier PCB light up, along with LEDs2&3 (red). LED4 may flicker initially but should not stay on. Check for a reading of between 0.75V and 3V across each safety resistor and verify that the two readings are close in value.

A typical reading will be just under 1V however as the output stage is

DANGER: HIGH VOLTAGES

High DC and high AC voltages are present in this circuit. The power transformer has either an **80VAC or 60VAC output and the amplifier power supply rails are a total of 114V or 84V DC**. DO NOT touch any part of the power supply or amplifier circuitry when power is applied otherwise you could get a severe electric shock.

The two LEDs on the power supply board indicate when power is present. If they are alight, the power supply and amplifier boards are potentially dangerous.

Using A Sewing Machine Bobbin To Wind The Air-Cored Inductor

Overseas readers have had trouble locating a source for the plastic bobbin used to wind L2, the 2.2µH air-cored inductor which is part of the output filter. You can't just use any old inductor here as it is must be perfectly linear to give good performance and only air-cored types can be relied on.

The plastic bobbins supplied by Jaycar or Altronics have an inner diameter of 13mm, outer diameter of 20mm and width of 8mm. Unfortunately, we've had trouble finding other sources of bobbins with these same dimensions.

Fortunately, it turns out that a common type of sewing machine bobbin has very similar dimensions and while these are normally made of steel (which would not be suitable), plastic types are now available. These appear to be made of some type of clear acrylic and they even have appropriately-sized holes in the right place for each end of the coil to emerge!

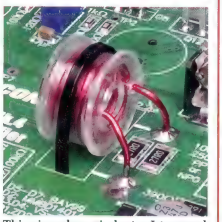
These bobbins have an inner diameter of 6mm, outer diameter of 20mm and width of 9mm. They are intended for use as cotton-feed spools in Singer, Janome and some Brother and Elna sewing machines – in fact, pretty much any domestic sewing machine.

For convenience, we can also supply one or more of these bobbins along with PCBs for the Ultra-LD Mk4 – see our website for details.

The accompanying photo shows a 2.2µH inductor wound using 1.25mm diameter enamelled copper wire on one of these sewing machine bobbins. The procedure is similar to that described in the article last month, except that we wound on four extra turns (ie, 17.5 turns total) to make up for the smaller inner diameter. Our LCR meter confirmed the resulting inductance is very close to the inductor used in our prototype, built on a Jaycar-sourced bobbin.

If using the winding jig described last month, you will need to reduce the spindle diameter in order to fit the smaller bobbin. This may be as simple as unwinding some of the electrical tape wound around the bolt. We wound some electrical tape on a 6GA self-tapping screw until we reached a diameter of about 6mm, making it a snug fit through the centre of the bobbin.

We were then able to wind the wire on with some difficulty (due to the increased curvature required by the smaller inner diameter). Try to pack the turns side-by-side. You should be able to wind on around six turns before having to start the second layer and you should reach 17.5 turns by the time the third layer is just about full. Note that while the wire specified will fit through the holes in the bobbin, it's a tight fit and they may not appear large enough at first. But we got it through.



This view shows inductor L1 wound on a sewing machine bobbin. You will need to wind on 17.5 turns of 1.25mm enamelled copper wire (four more than for the Jaycar & Altronics bobbins) to get 2.2µH.

Once you've finished winding, bend the wire over so it exits through a hole on the same side as the start. We applied two layers of clear heatshrink tubing to prevent the windings from moving. This inductor was used on our lower-power (110W) prototype, as you can see from the photo(s).

under-biased initially, there can be a small amount of non-damaging oscillation present which will result in a higher initial current draw.

Note that if you've fitted the 1000µF bypass capacitors, the reading will be much higher when they charge, starting at almost the full supply voltage and dropping to below 3V after a second or so. If the reading stays high, something is wrong, so switch off and check for faults such as short circuits, poor solder joints or incorrectly orientated or mixed up components. For example, if D3 and D4 were installed backwards, you will get virtually the fully supply voltage across the test resistors.

Fitting the fuses

Assuming it's OK, switch off and wait for the LEDs to go out, which will probably take a couple of minutes. That done, fit F1 and F2, then switch back on and re-check everything. This time LED2 and LED3 should light green but nothing else should change. If it does, then the output stage is suspect, eg, there could be an isolation failure on one of the output transistor insulating washers.

You can now check the output offset voltage by measuring between the top two pins (ie, the speaker output pins) of CON2. It should be less than 25mV and is usually about 10mV. **Be careful not to short the two pins together!**

Now rotate VR1's screw clockwise slowly while monitoring the voltage across a safety resistor. At first nothing should happen but eventually it will rise. This indicates that the V_{BE} multiplier is working; stop turning VR1.

Now rotate VR2 and check that the output offset voltage changes. You can trim it close to 0mV now, although you will need to make the final adjustment later. If you have a scope and signal generator, you can feed a low-level signal into the amplifier (<250mV RMS) and check that the output signal looks clean.

Note that with the safety resistors in-circuit, it won't drive a load, nor will it handle high voltage swings or high-frequency signals.

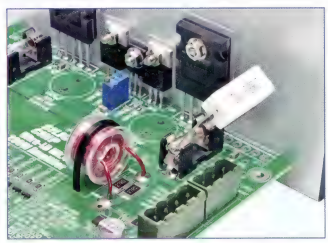
Quiescent current adjustment

Switch off, wait for the LEDs to go off and remove the safety resistors. The 68Ω 5W resistors can now be soldered across a pair of blown fuses to make handy resistor fuse adaptors; see the accompanying panel. Fit these in place of F1 & F2 and wire up the power supply direct this time, as shown in the chassis wiring diagram of Fig.21.

Given that the earlier tests were successful, it's unlikely anything will go wrong at this stage but it's still a good idea to have the safety resistors in place of the fuses initially. These limit the current through the output stage to about 840mA if there is a fault.

Note, however, that the 68Ω safety

Adjusting The Quiescent Current Through The Power Amplifiers



The quiescent current flowing in the output stage of each power amplifier is initially adjusted by installing 68Ω 5W resistors in place of the fuses. The voltage across one resistor is then monitored and trimpot VR1 adjusted for a reading of 9.5V for the full-power amplifier module or 4.75V for the lower-power version – equivalent to a quiescent current of 70mA.

The easiest way to connect the resistors is to "blow" the fuse wires in a couple of spare M205 fuses, then drill holes in the end caps and solder the resistors in place as shown. The original fuses can then be removed and the "modified" fuses clipped into place – see photo. Be careful that their leads don't touch anything while the module is powered up.

resistors will quickly burn out under such circumstances (since they would be dissipating close to 48W).

Now use the following procedure to set the quiescent current and trim out the offset voltage:

STEP 1: check that the safety resistors are installed and that their leads can't short to any adjacent parts (note: do NOT connect the loudspeaker to the amplifier during this procedure).

STEP 2: connect a DMM set to volts across one of the safety resistors (alligator clip leads are handy in this situation).

STEP 3: turn trimpot VR1 fully anti-clockwise. This can take as many as 25 turns but it will continue to turn even so. Many (but not all) multi-turn trimpots click when they are at the end-stop. If in doubt, check the resistance across it – it should be about 1kΩ.

STEP 4: check that the power supply is off and that the filter capacitors are discharged (LEDs off!), then connect the ±57V [±42V] supply to the module. Check that the supply polarity is correct, otherwise the amplifier will be damaged when power is applied.

STEP 5: apply power and check the voltage across the 68Ω resistor. It should be less than 1V (it may jump around a bit). If the reading is over 10V, switch off immediately and check for faults.

STEP 6: using an insulated adjustment tool or a small flat-bladed screwdriver, slowly adjust trimpot VR1 clockwise. Be careful not to short any adjacent components.

STEP 7: after a few turns, the resistor voltage should stabilise and start to rise. Continue until it reads around 9.5V [4.75V]. It may drift a little but should be quite steady.

STEP 8: switch off, wait for the capacitors to fully discharge (LEDs off) and replace the safety resistors with 6.5A [5A] fuses.

STEP 9: connect a DMM set to volts between TP5 (near the upper-left corner of the board) and TP7 (near the centre). If you have fitted PC stakes, you can use alligator clip leads (make sure they can't short to anything); otherwise you may need to get someone else to hold the probes in place while you perform the following steps.

STEP 10: reapply power and check that the DMM reads close to 7mV. If necessary readjust trimpot VR1 to bring the voltage close to this figure.

STEP 11: now check the voltage between TP4 and TP7. The reading should be similar. For the 200W module, do the same check with TP3/TP7 and TP6/TP7. This verifies that all the output transistors are working and sharing the load current more or less equally.

STEP 12: adjust VR2 until the voltage across the output pins is less than 0.5mV. This is easier to do if you screw a couple of bits of wire into the top two connections of the pluggable terminal block for CON2 and clip a DMM across it using alligator clip leads. **Be extra careful not to short the output terminals together!** Note that this is a trial-and-error process because you will probably find each time you remove the screwdriver from VR2, it will take several seconds for the output voltage to stabilise. You will need to make very small adjustments towards the end of the process.

Recheck the quiescent current

It's a good idea to recheck the quiescent current by monitoring the voltage between TP5 & TP7 after the amplifier has been idling for an hour or so with the lid on. If the reading is more than 15mV, readjust VR1 anti-clockwise to bring it back within the 7-10mV range. The stability is such that it should stay below 15mV but it's a good idea to check.

That completes the adjustments. Note that if you wish to repeat the above procedure (ie, with the 68Ω resistors in place), you will first have to reset VR1 to minimum (ie, fully anti-clockwise). If you don't do this, the amplifier may latch up when power is reapplied and burn out the safety resistors.

Troubleshooting

If there's a fault in the module, a likely symptom is either excessive voltage across the safety resistors or the amplifier output voltage is pegged near one of the ±57V supply rails.

If this happens, switch off and wait for the power supply capacitors to discharge. Then check that all the transistors are properly isolated from the heatsink.

If this checks out, apply power to the amplifier without the fuses or safety

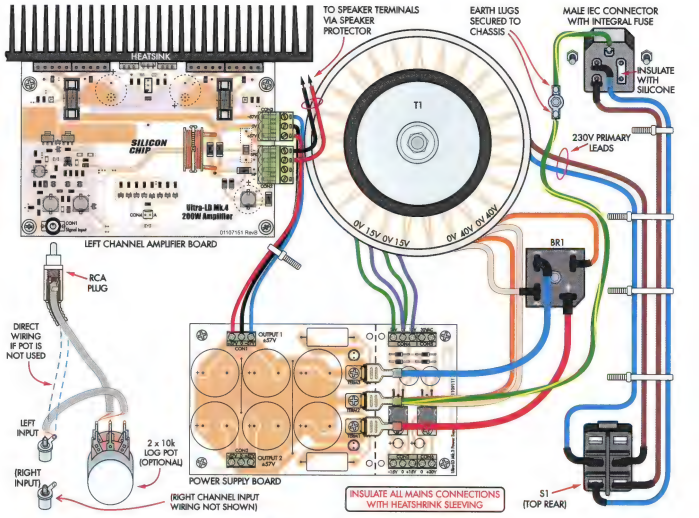


Fig.21: how to wire up the mains transformer, bridge rectifier, power supply board and amplifier module(s) to build a complete amplifier. The full-power version is shown here but the only differences for the lower power version are the power supply voltages and omission of one pair of output transistors. Most constructors will want to fit a volume control; use a 2x10kΩ log pot wired as shown or use our Ultra-LD Stereo Preamplifier, described in the November & December 2011 issues. Don't forget to properly insulate all mains wiring and ensure the chassis is properly earthed as shown.

resistors in place; ie, so that the output stage (Q7-Q13) is left un-powered. Now check the voltage between the bases of transistors Q7 & Q8, ie, between TP1 and TP2. This should be close to 2.2V.

If this voltage is too high and you can't reduce it with trimpot VR1, there could be a fault in the V_{BE} multiplier (transistor Q9 and its associated components) or an open circuit between it and the diode leads of Q10-Q13. This could be due to an open-circuit track on the PCB or more likely, missed solder connections on the output transistor leads.

If the voltage between the bases of transistors Q7 & Q8 is correct (ie, 2.2V), check the other voltages indicated on the circuit diagram. Note that the supply rails can vary by a few volts depending on your exact mains voltage, so some of the voltages can vary somewhat.

In addition, check the base-emitter voltage of every transistor in the amplifier. In each case, you should get a reading of 0.5-0.7V if the transistor is working correctly. If not, then either the transistor is faulty or the wrong type has been used in that location.

Making repairs

If you need to remove a faulty though-hole component from a double-sided PCB, the best approach is to first cut the body of faulty component away from its leads. It's then just a matter of grabbing them one at a time with pliers, heating the solder joint and pulling gently until the lead comes out.

Once the leads have been removed, use a solder sucker or vacuum de-soldering tool to clear the holes.

Replacing SMD components is generally not too difficult. If you have a hot-air station, it's simply a matter of heating the component until its solder joints melt and then lifting it off with a pair of metal tweezers. Note that doing this with a LED may damage its lens and it's definitely not recommended with the fuseholders as you will melt or burn the plastic before the part budges!

Having removed the part, it's then just a matter of putting some flux paste on each pad and placing solder wick on top, then pressing down on the wick with the soldering iron and, once the solder has melted, sliding it off the pad. This will generally leave

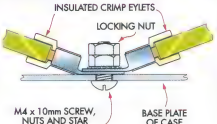


Fig.22: the chassis earth point is installed as shown here. Make sure it forms a very good electrical contact with the chassis (ie, scrape away any paint or coating under the eyelet lugs) and don't use this screw for any other purpose.

the pad clear of solder for fitting a new part. But don't heat it for too long or you risk damaging the board.

If you don't have a hot-air rework station, you can still remove SMD parts but it's a little more awkward. Basically, you need to heat the leads in a round-robin fashion until the part has heated up enough for all the solder to remain molten long enough for the part to be lifted off. It usually helps to add extra solder to each pin when doing this, bridging adjacent pins in the process so that you can heat multiple pins at once.

We've successfully used this technique to remove resistors, capacitors, SOT-23, SOT-23-6 and SOT-223 package devices; ie, it works with just about any type of SMD on this board.

Chassis assembly

If you want to build a complete stereo Ultra-LD Mk.4 amplifier, the easiest approach is to build the Ultra-LD Mk.3 amplifier as described in the March-May 2012 issues and simply substitute the new amplifier modules. If desired, the revised speaker protector module that we will be presenting next month could also be used.

Altronics have a complete kit for that project (K5165) as well as separate kits for the chassis (K5166), input selector (K5164), speaker protector (K5167), power supply (K5168) and preamplifier (K5169). Building it using these kits will be much easier than building from scratch, and give a professional appearance to the finished product.

We strongly recommend that if you are going to build the Ultra-LD Mk.4 with a preamplifier and/or input switching, you use the design we described in the November & December 2011 issues, eg, from the Altronics kits mentioned immediately above. This is one of the few preamplifier designs around with the low distortion and noise needed to do justice to the Ultra-LD Mk.4 module.

However, if you want to do it your own way, or just want to build a basic amplifier without the preamp, you can simply mount the modules in a suitable large steel case and wire them up as shown in Fig.21.

The chassis layout is important to achieve the stated performance, so be sure to follow these instructions. In addition, safety is of the utmost importance, especially for mains wiring and chassis earthing.

Basically, the amplifier module(s) and the power supply (along with the transformer) must be housed in an earthed metal case. This must be large enough to provide sufficient room between the transformer and the amplifier modules to avoid hum coupling. It's also critical to use shielded cable for all the audio signal wiring, ie, between the input connectors and amplifier module(s).

You will need a 2U or 3U extra-deep rack-mount metal case (or a similar enclosure) to fit a complete stereo amplifier. It will need to be quite strong to support the weight of the heatsinks and the transformer. Good ventilation is also important and ideally there should be vents immediately surrounding the heatsinks.

The power transformer and IEC connector should be mounted towards the back (either in the lefthand or righthand rear corner), while the amplifier modules can be positioned on either side of the case, near the front. The power supply board can then fit be-

You *MUST* Use A Loudspeaker Protector

AS STATED in the main body of the article, it's essential to use a loudspeaker protector with the Ultra-LD Mk.4 amplifier module (and with any other high-power audio amplifier module for that matter).

That's because if a fault occurs in the amplifier (eg, if one of the transistors fails), this could apply one of the full 57V or 42V supply rails to the loudspeaker's voice coil. As a result, the voice coil would quickly become red hot and burn out, irreparably damaging the speaker. This may also cause a fire!

This new loudspeaker protector module to be described next month in SILICON CHIP will prevent this from happening. Alternatively, you can use the Universal Speaker Protector & Muting Module described in the October 2011 issue (Altronics kit K5167) – see text.

In either case, the device quickly disconnects the loudspeaker(s) in the event of a DC output fault. It also provides muting at switch-on and switch-off to prevent audible thumps and includes an input for an optional temperature sensor to disconnect the loudspeaker(s) if the output stage heatsink rises above a preset temperature.

Parts List: Power Supply

1 PCB, code 01109111, 141 x 80mm
4 3-way PCB-mount terminal blocks, 5.08mm pitch (Altronics P2035A or equivalent) (CON1-4)
2 2-way PCB-mount terminal blocks, 5.08mm pitch (Altronics P2034A) (CON5-6)
3 PCB-mount or chassis-mount spade connectors (Altronics H2094)
3 M4 x 10mm screws, nuts, flat washers and shakeproof washers (if using chassis-mount spade connectors)
4 M3 x 9mm tapped Nylon spacers
10 M3 x 6mm machine screws
2 M3 shakeproof washers and nuts
1 150mm length of 0.7mm-diameter tinned copper wire

Semiconductors

1 7815 1A 15V positive linear regulator (REG1)
1 7915 1A 15V negative linear regulator (REG2)
4 1N4004 1A diodes (D1-D4)
1 5mm green LED (LED1)
1 5mm yellow LED (LED2)

Capacitors

6 4700µF 63V [50V*] electrolytic
2 2200µF 25V electrolytic
2 220µF 16V electrolytic

Resistors

2 3.3kΩ 5W

Parts For Complete Stereo Power Amplifier

2 Ultra-LD Mk.4 amplifier modules
1 Ultra-LD Mk.4 power supply module
1 speaker protection module (to be described next month)
1 vented metal case, 2U/3U rack-mount or similar size (eg, Altronics H5047)
1 chassis-mount IEC mains input socket with fuseholder (use Altronics P8324 for recommended case)
1 M205 5A [3A*] fuse
1 mains-rated power switch (eg, Altronics S4243A)
1 300VA transformer with two 40VAC 300VA windings and two 15VAC 7.5VA windings for 200W Ultra-LD Mk.4 module
OR
1 160VA transformer* with two 30VAC 169VA windings and two 15VAC 7.5VA windings for 120W Ultra-LD Mk.4 module
1 35A 400V chassis-mount bridge rectifier
1 white insulated chassis-mount RCA socket
1 red insulated chassis-mount RCA socket
2 red and 2 black chassis-mount speaker terminals (or two double speaker terminals)
1 10kΩ dual-gang log potentiometer with suitable knob (optional, for volume control)
M3 and M4 screws, washers & nuts for mounting bridge rectifier, PCBs and heatsinks
Mains flex (approximately 2m)
Mains-rated heavy duty wire (approximately 2m)
Shielded wire for input signals (approximately 2m)
Speaker cable (about 0.5m)
Heatshrink tubing
Fully-insulated 6.3mm spade crimp connectors (about 20)

Parts Availability

The power supply PCB (code 0110911) can be purchased from the SILICON CHIP Online Shop or you can purchase a complete power supply kit from Altronics, Cat. K5168.

* For 120W version

tween the amplifier modules, with its ±57V [±42V] outputs near the supply connector(s) on the module(s).

It's also vital to include a loudspeaker protection module (not shown in Fig.21) – see panel on previous page. This module can be mounted towards the centre-rear of the chassis, while the RCA input connectors can be mounted in the opposite corner to the mains input.

The volume control is optional but most constructors will want one, unless they are using an external preamplifier. No input switching is shown on Fig.21; the complete stereo amplifier described in the March-May 2012 issues has remote input switching with front panel buttons/indicator LEDs, as well as remote volume control.

Checking the wiring

Make sure that the chassis is securely earthed via the mains and be sure to insulate all exposed mains terminals with heatshrink sleeving, as shown in Fig.21.

Fig.22 shows how the earth lugs are secured to the chassis using an M4 x 10mm screw, a lock-washer and two nuts. Make sure that the earth leads are securely crimped or soldered to these lugs before bolting them to the chassis.

Once you've done this, use a multimeter to confirm the earth connection. You can do that by checking for continuity between the earth terminal of the IEC socket and the chassis.

Testing the power supply

Once the assembly is complete, check your wiring very carefully. In particular, make sure that BR1's positive and negative terminals connect to the correct terminals on the power supply board.

It's now time to check that the power supply is functioning correctly but first a warning: **the metal strap on the IEC mains socket that runs from the Active terminal to one end of the fuse has 230VAC on it. You should insulate this terminal using neutral-cure silicone sealant or you can cover the IEC socket with a rubber boot, eg, Jaycar Cat. PM-4016.**

To check the power supply, first make sure that the supply wiring is disconnected from the amplifier. That done, apply power and check the various DC outputs. You should be able to measure close to ±57V [±42V] on CON1 & CON2, +20V on CON6, ±15V on CON3 and 30VAC on CON5. If you don't get the correct voltages, switch off immediately and check for errors.

Next month

That's it for now. If you need more information on building the completed amplifier modules into a chassis, refer to the Ultra-LD Mk.3 stereo amplifier construction details in the March and April 2012 issues.

Next month, we'll have the complete constructional article for our revised Speaker Protection Module. This has a number of new features and improvements compared to the previous version which was described in the October 2011 issue. SC

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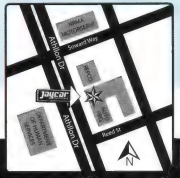

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SAVE $30

15A Intelligent Battery Charger MB-3623 **WAS $149**

Suitable for flooded and gel lead acid batteries including deep cycle batteries. The microprocessor controlled unit provides 4 stages of charge which can be pre-programmed or manually set for greater control.

- Input: 220 - 240VAC, 300W
- Output: 15A @ 12V / 7A @12V/24V / 2A @ 6V/12V/24V

FROM $199
SAVE UP TO $70

High Power 4-Stage 240V Battery Chargers

Tough mains powered and designed to quickly recharge 12V lead-acid batteries. Features smart 4-stage charging, over-charging and ouput short-circuit protection. Safe to leave connected indefinitely.

15A MB-3710 **WAS $249 NOW $199 SAVE $50**
40A MB-3715 **WAS $469 NOW $399 SAVE $70**

SF-2245

DOUBLE POINTS
FROM $17.95

Battery Isolation Switches

Commonly known as a kill switch, it electrically disengages the battery to help prevent fire and increase safety. Great for racing cars or even marine applications. 12V.

120A SF-2245 **$17.95**
500A SF-2247 **$49.95**

DOUBLE POINTS
FROM $79.95

140A Dual Battery Isolator

Allows two batteries to be charged from your engine alternator at the same time. The isolator automatically engages and disengages depending on the charge condition of the start battery.

- Voltage rating: 12VDC (max 15VDC)
- Cut in/off voltage: 13.7/12.8 VDC

STANDALONE UNIT MB-3685 **$79.95**
COMPLETE KIT Includes wiring hardware. MB-3686 **$149**

MEMBERS' OFFER
$30 OFF
MS-6174
Valid with purchase of MS-6170 or MS-6172

Digital DC Power Meters

Suitable for DC operation from 5 to 60V, these meters display and store power usage and are an ideal addition to low voltage DC circuits on boats, caravans, or solar systems.

0-20A WITH INTERNAL SHUNT
MS-6170 **$79.95**
0-200A TO SUIT 50MV EXTERNAL SHUNT
MS-6172 **$89.95**
USB DATA ADAPTOR MS-6174 **$99.95**

$9.95

Multi-Connect Battery Terminal HM-3089

Use this to terminate up to 4 electronic devices or as a bus-bar that connects to multiple devices. Perfect for simple wiring or other 12V applications where multiple accessory wiring is needed. Spade terminals included. Screws not required.

NEW
$29.95

Quick Release Car Audio Power Connector HC-4067

Quickly and safely remove your high power car audio, secondary battery or other high current DC set up. Comes with a bracket for secure mounting. High quality and durable ABS plastic. Rated up to 140A.

$49.95

250A Remote Battery Jumper Terminals HM-3075

Provides convenient access to the vehicle battery for charging or jump starting. Suits cars, boats, trucks and caravans. Includes protective red & black rubber covers.

See Pg 8 for T&Cs

DEAL OF THE MONTH:

POWER UP AND SAVE!

Benchtop Power Supplies

Our range of highly efficient and reliable benchtop power supplies are specially selected to suit your unique testing and servicing applications. They use proven technology and are designed to give long service life in workshop situations. Features include low noise, low ripple and protection against overload and short circuit. Available in fixed or variable voltage and current models, they make the most cost effective solution for your laboratory use, electronic and communications equipment maintenance.

	MP-3097	MP-3800	MP-3067	MP-3094
Features	Fixed input, fixed output voltage, also available in 5A & 20A models	Compact size, high current, variable output voltage	Automatic constant voltage/current, dual output with flexible connection	High powered, variable output voltage and current
Output Voltage	13.8VDC	0 to 24VDC	0 to 32VDC (x 2)	1 to 15VDC
Output Current	10A	15A	0 to 3A (x 2)	0 to 40A
Output Regulation	<5%	<1%	10mV max	50mV @10-100% load
Ripple Voltage	120mV	<3mVp-p	<1mV RMS	5mV RMS
Size (W) x (D) x (H)	153 x 233 x 100mm	148 x 162 x 62mm	260 x 400 x 185mm	200 x 215 x 90mm
Was Price	**$139**	**$149**	**$379**	**$469**

$109
MP-3097
SAVE $30

$119
MP-3800
SAVE $30

$329
MP-3067
SAVE $50

$399
MP-3094
SAVE $70

NERD PERKS

GET MORE PERKS FROM NERD PERKS!

Our CEO wanted a new and exciting name for our loyalty programme so we held a competition to see who could find us a name, and the name chosen was NERD PERKS!

- **For all existing members, benefits and points accumulated will remain**
- **If you are new to the club, join at our stores or via our website**

All existing members will receive the Nerd Perks card and workshop guide in the mail by late October!

Available from Early October!

For more details visit jaycar.com.au/nerdperks

15% OFF FOR REWARDS / NERD PERKS CARD HOLDERS

Motor Start Capacitors

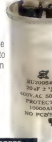
Ideal for starting single phase induction motors, these capacitors are suitable for motors operating at up to 400VAC. Lower ranges from 6uF to 12uF also available.

See website for details

- Built-in safety device

20UF RU-6606 **$16.95**

30UF RU-6608 **$16.95**



MEMBERS' OFFER **15% OFF!**

20VA Toroidal Transformers

With a low height of only 30mm, these toroids will fit into a 44mm rack case. Low electrically induced noise and high efficiency.

- Simple, quick, single bolt mounting
- Outer/Inner: 74mm/21 x 30mm

9+9 VOLTS MT-2082 **$24.95**

12+12 VOLTS MT-2084 **$23.95**

15+15 VOLT MT-2086 **$23.95**

MEMBERS' OFFER **15% OFF!**

72VA EI Core Transformer

MM-2012 **$27.95**

Type 2156 single winding transformer with 200mm fly leads on primary and secondary connections.

See website for our full range of EI Core and specifications.

- 24V, 72VA, 3A rated

MEMBERS' OFFER **15% OFF!**

Chassis Mount Solid State Relays

These high current relays have dielectrically isolated DC control inputs to control either AC or DC power circuits.

AC TYPE 40A 240VAC TRIAC SY-4084 **$47.95**

DC TYPE 100A 0-30VDC MOSFET SY-4086 **$49.95**

See Pg 8 for T&Cs

GREAT REPLACEMENTS

$14.95

SAVE $5

12VDC CCD Cameras Power Supply

MP-3011 **WAS $19.95**

500mA regulated switchmode plugpack ideal for CCD cameras. Terminates to a 2.1mm DC plug, centre positive.

FROM $34.95

SAVE UP TO $15

MP-3573

12VDC 7.5A Switchmode Power Supply

Power your 12V equipment with a cigarette lighter plug from mains power (240VAC). 12VDC.

7.5A MP-3575
WAS $39.95 NOW $34.95 SAVE $5

12.5A MP-3573
WAS $99.95 NOW $89.95 SAVE $10

FROM $59.95

Desktop Power Supplies

Versatile switchmode power supplies in a range of different configurations. All units have high output currents and are low-profile for easy mounting. All units include 2.5mm fixed output plug, except MP-3243 with 5 output plugs.

- IEC 240VAC lead sold separately (PS-4106)

12VDC 5A MP-3242 **$59.95**

12VDC 5A With 5 output plugs. MP-3243 **$64.95**

19VDC 3.4A MP-3246 **$59.95**

24VDC 2.7A MP-3248 **$59.95**

POWER ESSENTIALS FOR HOME & OFFICE

FROM $8.95

PS-4106

Mains Power Leads

See website for full range.

IEC FEMALE TO 240V 1.8M
PS-4106 **$8.95**

IEC FEMALE TO IEC MALE 1.8M
PS-4108 **$8.95**

IEC MALE TO GPO FEMALE 150MM
PS-4100 **$9.95**

FROM $10.95

MS-4073

4-Way Powerboards

All filtered and surge protected. Protect your expensive equipment against damage. 10A max.

4-WAY MS-4051**$10.95**

4-WAY + 2 X USB 2.1A Max MS-4073 **$24.95**

NOW $12.95 ea

SAVE $5

PP-4042

Mains Travel Adaptors

WITH USB WAS $17.95 EA

All adaptors include a 2.1A USB charge port eliminating the need to carry multiple chargers.

- Does not convert voltage

3 PIN TO EUROPE PP-4042
3 PIN TO UK/HONG KONG PP-4044
3 PIN TO USA PP-4046
2 PIN TO JAPAN PP-4048

Lithium Rechargeable Batteries

Suitable for LED torches and other applications. 14500 type.

3.7V 750MAH LI-ION BATTERY SB-2303

3.2V 600MAH LIFEP04 BATTERY SB-2305

ALSO AVAILABLE:

UNIVERSAL LITHIUM BATTERY CHARGER MB-3637 **$54.95**

DOUBLE POINTS

$9.95 ea

Batteries not included.

$39.95

DOUBLE POINTS

Universal Battery Charger

WITH USB MB-3639

Recharge various batteries (Ni-Cd,Ni-MH,Li-ion) found in digital cameras, MP3 players, etc. 1 x USB socket (0.5A). Mains and car adaptor included.

$24.95

NEW

USB Voltage & Current Tester XC-5074

Easy to use, it plugs into your device and displays the voltage and current the device uses.

- Voltage range: 3 to 6V
- Current range: 0 to 3A

SMART UPS TO PROTECT YOUR DATA

Protect your valuable setup with our value-for-money Uninterruptible Power Supplies (UPS) and keep your systems running long enough to save critical data when the power fails.

	MP-5224	MP-5207	MP-5212
Features	Line interactive, economical model	Line interactive, smart LCD desktop model	On-line, 2U rack mountable
Load Rating	600VA, 360W	1500VA, 900W	1000VA, 700W
Internal SLA Battery	12V/7AH x1	12V/9AH x2	12V/7AH x3
Output Waveform	Modified Sine Wave	Modified Sine Wave	Pure Sine Wave
Transfer Time	<10 ms	<10 ms	Instant
Power Outlets	6 x AUS (3 bypass, 3 mains)	2 x AUS mains	6 x IEC
Backup Time (65-70W/ 130-140W/ 190-210W)	31 mins / 11 mins / 4.5 mins	94 mins / 49 mins / 31 mins	95 mins / 47 mins / 32 mins
Was Price	$129	$319	$449

MP-5224 NOW **$109** SAVE $20

MP-5207 NOW **$269** SAVE $50

MP-5212 NOW **$419** SAVE $30

PERKS FOR REWARDS / NERD PERKS CARD HOLDERS

"Condura" Style DC Rocker Switches

Superb looking rocker switches that you see in 70-100ft luxury motor cruisers. All switches come with double-LED illumination, a standard rocker cover and a standard range of decals to customise the switch to your application. Typical decals include: windscreen wipers, horn, heater & many more.

- Rated 20A @12V, 10A @24V

See website for compatible laser-etched covers.

WHITE SK-0910 **$12.95**
RED SK-0912 **$12.95**
BLUE SK-0914 **$12.95**
ORANGE SK-0916 **$12.95**

SK-0912

MEMBERS' OFFER
4 FOR
$40*
SAVE $11.80

*Valid for purchase of SK-0910, SK-0912, SK-0914 or SK-0916

Quick Charge Your Electronic Devices

MP-3618 **$24.95**

This twin USB charger socket is designed to be professionally panel mounted for automotive and marine applications. Comes complete with a protective cap with short-circuit protection. Easy installation.

- Input: 12-24VDC
- Dual USB outputs: 5VDC, 3.1A (shared)

MEMBERS' OFFER
15% OFF!

Marine Grade Switch Panels

WITH CIRCUIT BREAKERS

Can be mounted either vertically or horizontally. 10A, 6A, 5A and 4A rated circuit breakers. Soldered to a 10A rated illuminated rocker switch which have 4.8 QC tabs and are single pole.

- ABS plate with 10A rated illuminated rocker switches

4 WAY SZ-1902 **$34.95**
6 WAY SZ-1903 **$44.95**

MEMBERS' OFFER
15% OFF!

*See Pg 8 for T&Cs

"Jow" Cable Clamp Connectors

Insert wire then snap shut. The connector blades borrow the IDC configuration that cut through the wires to create a connection. Handles up to 600V.

"I" TYPE FOR END TO END CONNECTIONS:

3A 6 PACK PT-4640 **$4.95**
10A 4 PACK PT-4641 **$4.95**
20A 2 PACK PT-4643 **$5.95**

"T" TYPE FOR PARALLEL CONNECTIONS:

3A 6 PACK PT-4650 **$5.95**
10A 4 PACK PT-4651 **$5.95**
20A 2 PACK PT-4653 **$6.95**

PT-4640

NEW

MEMBERS' OFFER
15% OFF!

DC-to-DC Converter Modules

Outputs user selectable voltages (excluding AA-0236) with protection against short-circuits, overload and overheating. *See website for details.*

6-28VDC INPUT, 3-15VDC OUTPUT
AA-0236 **$24.95**

6-14VDC INPUT, 11-26VDC OUTPUT
AA-0237 **$29.95**

24VDC INPUT, 12VDC OUTPUT
AA-0238 **$24.95**

AA-0236

MEMBERS' OFFER
15% OFF!

Panel/Surface Mount LED Voltmeter and Ampmeter

OP-5584 **$39.95**

Monitor your battery voltage and current draw easily by following the wiring diagram to measure 5-30VDC, and 0 to 10A DC.

- Panel/surface mount hood supplied
- Connection via 6.3mm spade termials

NEW

MEMBERS' OFFER
15% OFF!

12VDC Enclosed Switchmode Power Supplies

Highly efficient and reliable modular power supplies with broad input voltage tolerances.

25W MP-3160 **$44.95**
60W MP-3170 **$59.95**
150W MP-3185 **$94.95**

MP-3160

MEMBERS' OFFER
15% OFF!

MP-3352

MEMBERS' OFFER
15% OFF!

24-12V DC-DC Converters

Converts 24VDC to 12VDC so you can use accessories designed for 12V vehicles.

10A OUTPUT With Cigarette In/Out. MP-3352 **$74.95**

5A OUTPUT With 1A USB. MP-3354 **$59.95**

MI-5107

MEMBERS' OFFER
15% OFF!

24V Portable Power Inverters

High quality and reliable modified or pure sine wave inverters with USB port and offer standard protection features: 24VDC input, 230VAC output.

MODIFIED SINEWAVE:

400W MI-5107 **$89**
2000W MI-5116 **$419**

PURE SINEWAVE:

360W MI-5703 **$269**
2000W MI-5712 **$1199**

MF-1080

MEMBERS' OFFER
15% OFF!

Dielectrically Isolated Stepdown Transformers

Quality fully-enclosed stepdown transformer with approved 3-wire power cord & two-pin US 110 - 115V socket. 240VAC to 115VAC isolated.

120W MF-1080 **$109**
250W MF-1082 **$149**
500W MF-1084 **$255**
1000W MF-1086 **$419**

MEMBERS' OFFER
15% OFF!

Variable Laboratory Autotransformer (Variac)

MP-3080 **$229**

This heavy duty unit enables the AC input to a mains powered appliance to be easily varied from 0 to full line voltage (or greater).

- Rated power handling: 500VA (fused)
- Output Voltage 0 to 260VAC @50Hz

COMING SOON

SIGN UP* IN STORE
OR VISIT OUR WEBSITE

*Conditions apply. See website for T&Cs

$5.95
DOUBLE POINTS

Mini Coil Pack

LF-1050

Build your own AM radio with this pack of 4 standard AM transistor radio coils (includes 1 x red, 1 x black, and 2 x white). IF, osc, etc.

FROM $7.95
DOUBLE POINTS

EMI Filters

MS-4000

Designed to reduce line-to-ground interference or when mains cords are fixed to the outside chassis and an IEC320 inlet is not suitable. Rated for 125 or 240VAC, 50 or 60Hz.

PCB MOUNT MS-4000 **$7.95**
CHASSIS MOUNT MS-4001 **$9.95**

LF-1290

FROM $9.95
DOUBLE POINTS

Round Cable Noise Suppression Sleeves

Add extra noise suppression to mains cables with this simple hinged ferrite core. Snap-on design for quick installation. *See website for more details.*

SUITS UP TO 12MM DIA
LF-1290 **$9.95 EA**

SUITS UP TO 8.2MM DIA
Pack of 4 LF-1292 **$12.95**

SUITS UP TO 7.0MM DIA
Pack of 2 LF-1294 **$9.95**

SOLAR PACKAGE & DEAL

290W Solar Package

ZM-9306 **TOTAL VALUE $1081.90**

Clean renewable energy wherever you go. Solar-convert your 4WD or caravan to generate sufficient power to operate your favourite appliances off the grid.

PACKAGE INCLUDES:

2 X 145W MONOCRYSTALLINE SOLAR PANEL
ZM-9087 **$399 EA**

1 X 12V 30A CHARGE CONTROLLER
MP-3722 **$199**

3 X PV CONNECTOR FEMALE PS-5100 **$7.50 EA**

3 X PV CONNECTOR MALE PP-5102 **$7.50 EA**

1 X Y-LEAD 2 SOCKET TO 1 PLUG
PS-5110 **$19.95**

1 X Y-LEAD 2 PLUG TO 1 SOCKET
PS-5112 **$19.95**

$930
ZM-9306

SAVE OVER $150

FREE QUICK CHANGE CRIMP TOOL & PV CRIMP DIE FOR MEMBERS
TH-2000 + TH-2010

TH-2000 VALUE AT $49.95
TH-2010 VALUED AT $24.95

290W Solar Upgrade Deal

$1399

SAVE OVER $259

TOTAL VALUE $1658.85

Add battery and LED lights for a complete self-sustained power solution.

DEAL INCLUDES:

1 X 290W SOLAR PACKAGE ZM-9306 **$930**
1 X 100AH DEEP CYCLE GEL BATTERY SB-1695 **$429**
1 X BATTERY BOX WITH ACCESSORIES HB-8500 **$99.95**
2 X IP67 FLEXIBLE LED LIGHT STRIP ST-3950 **$99.95 EA**

150Ah 12VDC AGM Deep Cycle Battery

SB-1822

Designed to perform in harsh tropical conditions! With a superior high rate discharge performance and higher cycle service life, this battery is perfect for a wide array of applications including remote solar systems, 4WD, caravan, RV, motorhome, and marine applications.

- Small footprint to suit installations in tight areas
- 123(W) x 556(D) x 296(H)mm, 52kg

Not stocked in all stores but can be ordered. Check your nearest store for availability.

$769

DOUBLE POINTS

Solar Panel Mounting Brackets

Your ideal solution for mounting solar panels in caravan, motor home, shed or marine applications. These brackets provide secure and easy mounting, and they also space the panel up to provide the necessary airflow. *See website for full range.*

FIXED ALUMINIUM SIDE BRACKET
HS-8780 **$7.95 EA**

FIXED ABS SIDE BRACKETS White.
HS-8862 **$19.95 PAIR**

ADJUSTABLE 45° ALUMINIUM BRACKET
HS-8785 **$74.95 EA**

FROM $7.95

HS-8780

Solar System Cables

Very tough cable, specifically suited for the rigours of outdoor use in solar panel installations. Dust, age and UV resistant, tinned copper conductors to minimise corrosion.

4MM² 58A RATED WH-3121 **$4.20/m**
6MM² 76A RATED WH-3122 **$7.20/m**

FROM $4.20/m

SOLAR SYSTEM ESSENTIALS

FROM $9.95

SZ-2090

Power Distribution Posts

Heavy duty stainless steel posts mounted on a moulded plastic base. Three versions available with single connection or bridging plate to suit a variety of power distribution applications.

- 45(W) x 43(L) x 35(H)mm
- Mounting hole: 4.5mm (Dia)

M10 SINGLE
SZ-2090 **$9.95**

M8 TWIN SZ-2092 **$10.95**
M6 TWIN SZ-2094 **$10.95**

$9.95

High Current Slow Blow Fuses

Designed for high current protection. these bolt-down fuses eliminates nuisance blowing during temporary, short duration overloads. Commonly used for battery and alternator connections. Fuse holder sold separately.

- Rated up to 32V AC or DC
- Terminal studs 6mm

FUSE 125A SF-1982
FUSE 250A SF-1984

ALSO AVAILABLE:
FUSE HOLDER
SF-1980 **$24.95**

SZ-2081

$34.95

Heavy Duty Panel Mount Circuit Breakers

High quality units with multi-wire gauge inputs/outputs, perfect for high powered car audio, automotive or solar installations. 85(W) x 68(H) x 35(D)mm.

60A SZ-2081
120A SZ-2083
200A SZ-2085

Solar Charge Controllers

Efficiently charges a vast selection of batteries from a wide range of solar panels. This unit is capable of handling all solar charging requirements while protecting your battery. Additional features include adjustable charging voltage, automatic dusk-till-dawn on/off, overload protection, etc. *See website for full details*

12V 20A MP-3120 **$149**
12V 30A MP-3722 **$199**
12V/24V 30A MPPT MP-3735 **$259**

MP-3129

FROM $149

NERD PERKS COMING SOON

SIGN UP' IN STORE
OR VISIT OUR WEBSITE

'Conditions apply. See website for T&Cs

DOUBLE POINTS FOR REWARDS / NERD PERKS CARD HOLDERS

$11.95

DOUBLE POINTS

NEW

Stackable 15A Anderson® Data Connectors PT-4403

Stack this with the PP15 series 15A Anderson® connector (PT-4402) for DC and signal wiring connectivity. Provides a secure quick disconnect for power and signal distribution systems.

ALSO AVAILABLE:
15A POWERPOLE PT-4402 **$3.95**

$12.95

PT-4436

DOUBLE POINTS

4-Way 15A Anderson® Connectors

Housed in high impact and corrosion-resistant shell, these multi-connectors allow easy connection and disconnection of electrical equipments. Also available with latch for use in applications where shock or vibration may be severe.

4-WAY 15A PT-4434
4-WAY 15A WITH LATCH PT-4436

FROM $14.95

DOUBLE POINTS

PT-4429

NEW

Waterproof Boots

FOR ANDERSON® CONNECTORS

Durable and waterproof soft shell boots. The terminals of the rubber boot can also be customised to fit cables in-between 12-6 AWG (4-16mm²) wires. Easy to use. Mountable.

50A MALE PT-4428* **$14.95**
50A FEMALE PT-4429 **$14.95**
120A MALE PT-4431 **$17.95**
120A FEMALE PT-4432 **$17.95**

**Due early October.*

FROM $16.95

PT-4442

DOUBLE POINTS

Anderson® Adaptors

Easily adapt or extend your 50A Anderson® connector with the following options. Adaptor includes 300mm cable length.

5M EXTENSION LEAD PT-4440 **$74.95**
PIGGY BACK LEAD PT-4442 **$34.95**
15A CIGARETTE PLUG LEAD PT-4446 **$16.95**
15A CIGARETTE PLUG SOCKET PT-4448 **$16.95**
INSULATED BATTERY CLAMPS PT-4449 **$19.95**

DOUBLE POINTS

INTRODUCING DUINOTECH! 100% ARDUINO COMPATIBLE

	CLASSIC XC-4410	LITE XC-4430	MEGA XC-4420
Microcontroller	ATmega328P	ATMega32u4	ATMega2560
Clock	16MHz		
Flash Memory	32Kb	32Kb	265kB
SRAM	2kB	2.5Kb	8kB
Digital I/O Pins	14	7	54
Analog Pins	6	12	16
Size (W) x (L) x (H)	75 X 53 X 13mm	75 X 53 X 13mm	108 X 53 X 15mm
RRP	$29.95	$29.95	$49.95

If you have already immersed yourself into the exciting world of Arduino, or wanting to, then you'll love our extensive new range of Arduino compatible products we've affectionately named, **duinotech**. Here's just a small selection of the duinotech products on offer at Jaycar to build whatever creation you desire, from controlling lights or motors, to complete robotics applications. To learn more, download simple projects to get you started.

Visit our dedicated website deca.jaycar.net.

duinotech

NEW

FROM $29.95

XC-4410

BUILD YOUR OWN PCDUINO ROBOT

FREE 1.8m MICRO USB CABLE* FOR MEMBERS WC-7724

WC-7724 VALUED AT $8.95

FROM $89.95

XC-4352

PCDUINO V3.0

A high performance single board mini PC with Dual Core A20 processor. Comes pre-loaded with Ubuntu Linux and XBMC Media Centre, which can be replaced by Android OS if you prefer. Features microSD socket, 14 digital I/O, six analog inputs, two PWM outputs, SATA, Ethernet and HDMI ports. Great for robotics, home theatre, signage, electronic control and various other applications.

V3.0 NANO* XC-4352 **$89.95**

V3.0 WITH WI-FI XC-4350 **$119**

**Nano version available without Wi-Fi or LCD connector (LVDS) for compact applications.*

NERD PERKS

1 2 3 4 5 6 7

START YOUR DUINOTECH PROJECTS HERE

Duinotech Experimenter's Kits

Looking to get into Arduino but don't quite know where to start? Our range of experiments kits are the answer. Each kit contains a duinotech board, a breadboard, jumper wires and a wide range of peripherals. 100% Arduino compatible.

See online for full contents.

NANO KIT XC-4285* **$79.95**

MEGA KIT XC-4286* **$89.95**

**Due early October.*

XC-4285

NEW

FROM $79.95

COMING SOON

SIGN UP* IN STORE OR VISIT OUR WEBSITE

**Conditions apply. See website for T&Cs*

FROM $34.95

KR-3162

Robotics Motor Chassis Kit

Creating your own robot has never been easier. Ideal for duinotech, Arduino and pcDuino projects, these kits include motors, wheels, tyres and two pre-drilled mounting plates.

2-WHEEL DRIVE KIT KR-3160* **$34.95**

4-WHEEL DRIVE KIT KR-3162* **$44.95**

ALSO AVAILABLE:

SPARE WHEEL/ MOTOR YG-2900* **$9.95**

**Due early October.*

BUILD YOUR OWN DUINOTECH ENVIRONMENT METER TO MEASURE TEMPERATURE & HUMIDITY

DOUBLE POINTS

$8.95

12VDC PCB Mount Relay

SY-4052

DPDT, 2 x 5A @30VDC or 2 x 5A @240VAC contact rating.

DOUBLE POINTS

$23.95

Humidity/Temperature Sensor

XC-4246

Measures temperature and relative humidity using a simple interface that requires just three wires to the sensor: GND, power, and data. 100% duinotech/ Arduino compatible.

- Temperature: -4°C to +125°C (±0.5°C)
- Humidity: 0 to 100% (±2-5%)

DOUBLE POINTS

$34.95

8-Channel Relay Shield

XC-4276

Drive up to 8 relays from your Arduino using just 2 I/O pins. It communicates with your board using I2C, so you can even stack several shields together to drive 16, 24, or more outputs. 100% duinotech/ Arduino compatible.

FROM $1.75

PH-9206

AA Battery Holders

6 X AA 2 BY 3 SIDE BY SIDE PH-9206 **$1.75**

8 X AA 2 ROWS OF 4 SQUARE PH-9209 **$1.95**

DOUBLE POINTS

NEW

$9.95

Assorted Jumper Leads Kit WC-6029

Great for duinotech/Arduino projects, school experiements or other hobbyist activities. Contains 90 leads measuring 220mm long.

Due early October.

DOUBLE POINTS

FROM $12.95

PB-8814

Solderless Breadboards

Two sizes of breadboards to suit all your project needs.

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PRODUCT SHOWCASE

Android smartphone temperature datalogger from Ocean Controls

The TagTemp-NFC is a temperature datalogger with a Near Field Communication (NFC) interface. An Android smartphone with the LogChart-NFC app can configure and download data from the TagTemp-NFC by holding the smartphone close to the TagTemp.

The TagTemp NFC was designed primarily for monitoring the temperature of medical shipments but has numerous other uses. It is fitted with an external temperature sensor on a 30cm lead (other lengths are available) and is able to store up to 4000 records. The internal battery life is typically 400 days.

The LogChart-NFC app allows the user to view and graph the temperature history. The NOVUS Cloud Portal is offered as an optional service to TagTemp-NFC users that make use of Android smartphones. LogChart-NFC android app can be configured to send out temperature recordings read from TagTemp-NFC devices straight to the internet portal.

Once stored on NOVUS Cloud, records can be checked from any internet browser.

Price is $85+GST.

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Q: When is a breadboard not a breadboard?
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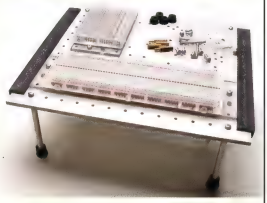
For a start, the Threadboard isn't simply a breadboard – it's a system. It consists of a thick (4mm) 5083-grade aluminium base (a great heatsink!) with a matrix of 3mm tapped holes. The Threadboard is also available in HDPE plastic and both have two removable side bumpers for protection.

The holes are spaced to accept a large (830 hole) and small (400 hole) somewhat traditional prototyping boards – these are amongst the nicest we've seen.

But wait, there's more! In addition, the Australian-designed and manufactured base is also drilled and tapped to suit a variety of popular boards such as Arduino, Raspberry Pi, Beagle Board and Intel Gallileo. Because of the number and spacing of holes, a range of PCBs can also be fitted. Add to that the range of accessories, including feet, long legs, stand-offs, M3 screws in various lengths and washers and you have a real development system – suitable for the dedicated engineer or the raw hobbyist.

And unlike any prototype system we've ever seen, both sides of the Threadboard can be used (with links through unoccupied holes). This is one product that everyone involved in electronics, at any level, should have on their workbench.

We know where one is staying!



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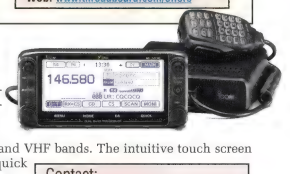
Icom Australia showcasing two D-Star radios

The ID-51A PLUS UHF/VHF Digital Transceiver (left) is the evolution of the successful ID-51A VHF/UHF Digital Transceiver.

The new model incorporates popular features from the original unit including integrated GPS, independent AM/FM receiver and V/V, U/U, V/U Dualwatch but also includes enhancements for digital operation and compatibility with the RS-MS1A free Android application.

The ID-5100A D-star digital and analog FM transceiver 2m/70cm dual band mobile (above right) is designed with D-STAR digital voice (DV) and data capability.



It has a large touch-screen LCD, two independent receivers and up to 50W output power on both UHF and VHF bands. The intuitive touch screen interface provides quick and smooth operation.

It also has an SD card slot for voice and data storage and a built-in GPS receiver.

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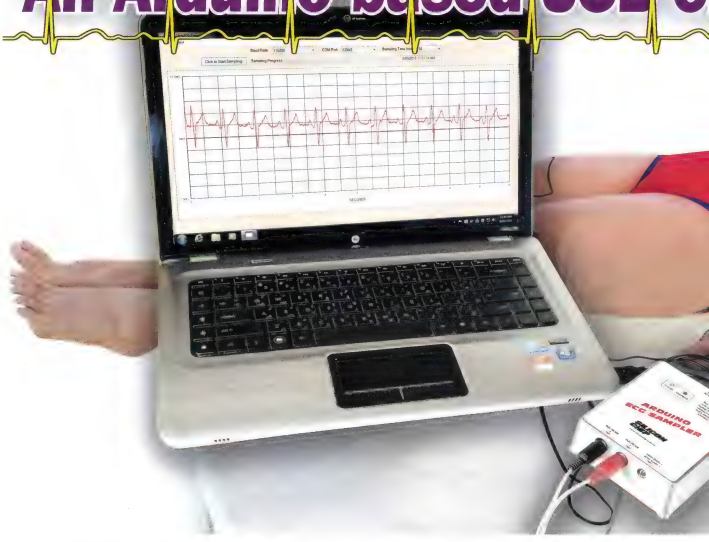
An Arduino-based USB e



Here's an easy-to-build Arduino project which will let you take your own electrocardiogram (ECG) and display it on a laptop PC. The software lets you read, display, save and print the electrical waveform generated by your heart – or anyone else's. It connects to your laptop via a USB cable, which also provides the low power it needs to operate.

AN ELECTROCARDIOGRAM or "ECG" is a piece of medical equipment used to measure and record the voltages produced as a result of heart muscle activity.

By attaching a pair of electrodes (or "leads" as they are known in the trade) to the skin of your wrists, ankle or chest, this PC-Driven ECG project can display, record or print out the same kind of ECG waveform via your personal computer.

Why would you want to build one? Just looking at the waveforms generated by your heart can be both fun and educational. You can monitor changes to your heart under various conditions, as your heart is affected by many things including emotions and mental and physical activity – even breathing.

All of these factors have a demonstrable effect on the heart's ECG waveform. Being able to show this easily, safely and at low cost is an added bonus.

Professional ECG machines can cost anything from $5000 up and while this project is not intended to be used as a diagnostic device, the displayed, recorded and printed waveforms are of a quality approaching that of professional machines.

In many ways, this new ECG Sampler can be seen as a much improved Mk2 version of the project described in the February 2005 issue of SILICON CHIP. The new design is based on a low-cost Arduino Uno/Freetronics Eleven microcomputer module, which con-

ectrocardiogram

By JIM ROWE

trols the actual sampling and sends the samples back to the laptop.

Note that to ensure complete safety, the unit should only be used with a laptop PC running on batteries. It should not be used with a PC (desktop or laptop) connected to the 230V mains supply – see warning panel later in this article.

Arduino shield

It does this under the direction of a small firmware program "sketch" stored in the micro's flash memory. To adapt the Arduino module for sampling the low-level signals picked up by ECG electrodes, we have designed a front-end "shield" module which plugs into the top of the Arduino module in the usual way.

The shield provides a high-gain (1000x/2000x) differential amplifier input stage, plus a 3-pole low-pass filter to reduce the sampler's susceptibility to 50Hz hum.

The Arduino and our ECG Sampler Shield are both powered from the laptop PC via the USB cable, so there's no need for a separate power supply. The total current drawn by the sampler is less than 65mA.

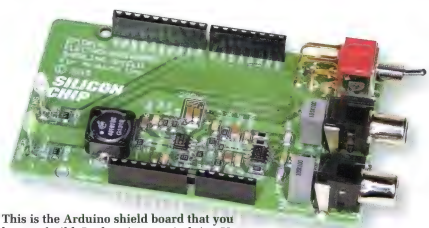
It's easy to use, with all the Sampler's functions controlled by a Windows-based GUI program running on the laptop PC and written in Visual C++. Both the Arduino micro's firmware program sketch and the Visual C++ PC program executable can be downloaded (free for subscribers) from the SILICON CHIP website: www.siliconchip.com.au

To allow the laptop to communicate with the Arduino via a USB cable, you'll also have to download and install a special USB virtual COM port driver. This can be downloaded from either the main Arduino website or the Freetronics website.

While you're hooked up to the Arduino website, you'll also need to download and install the latest version of the Arduino IDE (integrated development environment) package. That's because you'll need this to up-

DISCLAIMER

This project has not been designed for medical diagnosis. Correct interpretation of ECG waveforms and tracings is a complex and skilled procedure and requires proper medical training. The USB/ECG is presented here as an instructive and educational device only. If you are concerned about the health of your heart, consult your GP or a heart specialist.



This is the Arduino shield board that you have to build. It plugs into an Arduino Uno or Freetronics Eleven module.

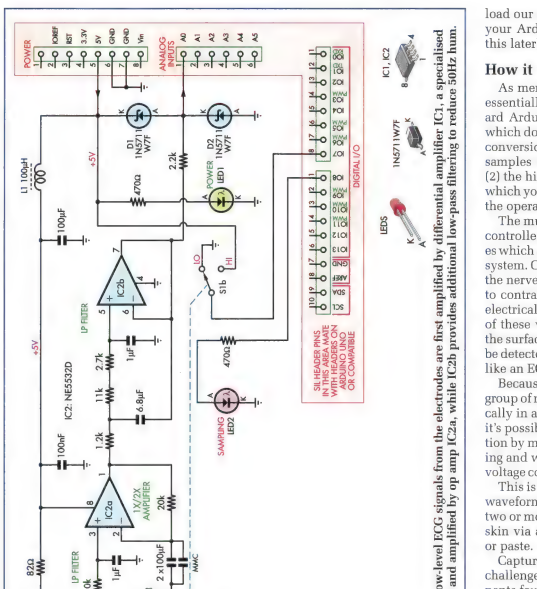


Fig.1: the ECG Sampler Shield circuit uses just two ICs. The low-level ECG signals from the electrodes are first amplified by differential amplifier IC1, a specialised instrumentation amplifier. Its output is then low-pass filtered and amplified by op amp IC2a, while IC2b provides additional low-pass filtering to reduce 50Hz hum.

load our sampling firmware sketch to your Arduino micro (more about all this later).

How it works

As mentioned above, the project is essentially in two parts: (1) a standard Arduino microcomputer module which does the ADC (analog-to-digital conversion) sampling and sends the samples back to the laptop PC; and (2) the high-gain ECG Sampler Shield which you need to build. We'll discuss the operation of the shield first.

The muscles of the human body are controlled by electrochemical impulses which are distributed by the nervous system. On reaching their destination, the nerve impulses cause the muscles to contract and produce much larger electrical voltages. A small proportion of these voltages is conducted out to the surface of the skin, where they can be detected using sensitive equipment like an ECG.

Because the heart is a large, complex group of muscles which contract cyclically in a preset sequence (see panel), it's possible to study its overall condition by measuring the amplitude, timing and waveform of the heart muscle voltage components found on the skin.

This is the reason for capturing ECG waveforms, which are obtained using two or more electrodes attached to the skin via a conductive saline solution or paste.

Capturing ECG waveforms is quite a challenge, because the voltage components found on the surface of the skin are quite low in amplitude – around 1mV peak-to-peak, depending on the positions of the electrodes and the resistance between them and the skin. That's about 1/10,000th of the voltage of a standard 9V battery!

So we need to feed these tiny voltages through a high-gain amplifier, to display or record them. To make the job that much harder, the tiny voltages we want to measure are usually completely swamped by 50Hz hum, picked up by our bodies from the fields surrounding the AC wiring in our homes and offices etc.

Fortunately, we are only interested in the voltage differences between the two electrodes that are being used, whereas the 50Hz hum picked up by the electrodes is virtually the same regardless of their position on the body. In other words, the 50Hz hum is a "common mode" signal, while

the tiny ECG voltages are "differential mode" signals.

By using a highly-balanced differential amplifier as the input stage of the ECG amplifier, we can cancel out most of the common-mode 50Hz hum before the differential ECG voltages are amplified. By the way, the connections between the electrodes and your skin play an extremely important role in this hum cancellation, because if one connection is poor, this can upset the balance of the input amplifier.

Most of the remaining 50Hz signals are removed by low-pass filtering in the later stages of the amplifier. So the output of the amplifier provides relatively clean amplified ECG signals, with little residual 50Hz hum.

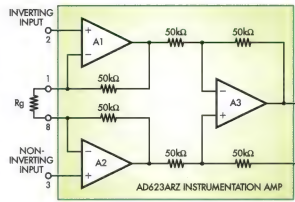


Fig.2: inside the AD623ARZ instrumentation amplifier. Op amps A1 & A2 are matched gain input stages and these feed a balanced subtractor output stage based on op amp A3. The resistors are laser-trimmed to achieve the required precision.

Circuit details

You can see how this is all done by referring to the circuit of Fig.1. The shielded electrode leads are brought into the ECG Sampler Shield via connectors CON1 & CON2 and then fed through 1µF capacitors and series 4.7kΩ resistors to the inputs of IC1.

IC1 is an Analog Devices AD623-ARZ, a specialised instrumentation amplifier offering very highly balanced differential inputs and hence very high common-mode signal rejection, combined with high gain.

A simplified version of the circuitry inside the AD623 is shown in Fig.2 and it is essentially three op amps in one: two matched-gain input stages feeding a balanced "subtractor" output stage. The overall AD623 gain for differential-mode signals is set by external resistor Rg, which gives a gain of 1000 times (60dB) when using a value of 100Ω.

To ensure that IC1 can deliver maximum undistorted output level (and to ensure that the Arduino ADC used for sampling the amplified signals can handle the largest signal swing), we connect IC1's reference signal input (pin 5) to a low-impedance source of +2.5V DC (ie, half the 5V supply). This is provided by a voltage divider comprising the two 3.0kΩ resistors and thereby sets the zero-signal output level of IC1 to the same level. The two 2.2MΩ input bias resistors for IC1 are also returned to the same +2.5V point.

Since IC1 operates with such a high gain, we also need to prevent it from amplifying any stray RF signals that may be picked up by the electrode leads (or the subject's body). This is the purpose of the 1nF bypass capacitors on each input of IC1 and also the 47nF capacitor between the two inputs. All three capacitors form a balanced low-pass filter, in conjunction with the two 4.7kΩ input series resistors.

The rest of the ECG Sampler Shield's amplifier and filter circuitry is based around IC2, an NE5532D dual low-noise op amp. The output from IC1 is fed to the input of IC2a via a low-pass filter formed by a series 10kΩ resistor and a 1µF capacitor, to give a corner frequency of about 17Hz and an attenuation of about 9dB at 50Hz.

IC2a provides a small amount of fixed amplification for the ECG signals. The gain here is 1x or 2x, as set by switch S1. The LO position of the switch gives unity gain (1x), while the HI position provides a gain of 2x. The overall ECG signal gain for the two switch positions is thus 1000 and 2000 times, respectively.

IC2b provides additional low-pass filtering, to further reduce 50Hz hum. With the R and C values shown, this filter stage has a corner frequency of about 15Hz and provides a further attenuation of about 21dB at 50Hz. At the same time, it has unity gain for the low-frequency ECG signals.

So at the output of IC2b (pin 7) we end up with reasonably clean ECG

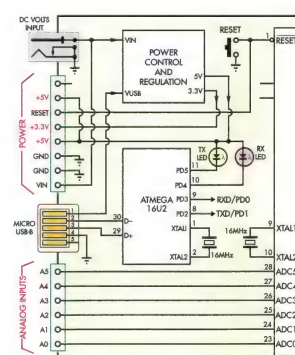


Fig.3: block diagram of the Arduino Uno/Freetronics Eleven module. It's based on two Atmel microcontroller chips: an ATmega328P and an ATmega16U2. The 328P micro is used as the module's main CPU, while the 16U2 handles communication with the PC via the module's USB port.

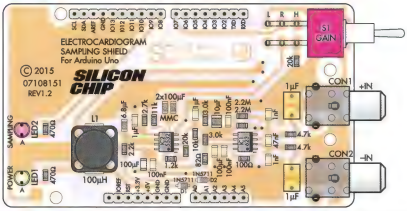
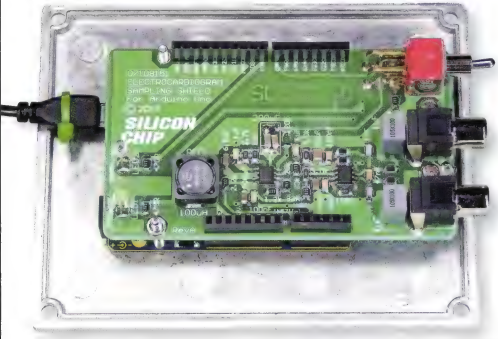


Fig.4: follow this parts layout diagram to build the shield PCB. Fit the SMD devices first before installing the larger through-hole components (see text).



Compare this photo with Fig.4 when building the shield PCB. The completed PCB is shown here plugged into the Arduino module on the case lid.

signals (although still with some residual 50Hz hum), amplified either 1000 or 2000 times, depending on the setting of S1.

Diodes D1 & D2, together with the series 2.2kΩ resistor, ensure that the amplified ECG output signals fed out to the Arduino ADC via the A0 pin are prevented from swinging below -0.3V or above +5.3V. This is to protect the Arduino's ADC input from overload damage.

The purpose of the second pole of gain switch S1b is to allow the Arduino to sense the current switch position, so that it can inform the software running in the laptop. As shown, S1b's rotor is connected to the Arduino's IO7 pin (used as an input), so this pin is pulled low (ie, to 0V) in the LO switch position and high (+5V) in the HI gain position.

The only other main circuit components are indicators LED1 & LED2. LED1 is a power indicator, to show that the ECG Sampler is connected to your laptop and "ready to roll". LED2 is turned on by the Arduino during sampling via the IO8 pin, to indicate that sampling is taking place.

Arduino in brief

Now let's take a quick look at the other half of the ECG Sampler: the Arduino Uno microcomputer module or its 100% compatible Australian incarnation, the Freetronics Eleven.

Arduino Uno seems to have been the one primarily responsible for Arduinos becoming a worldwide phenomenon so quickly. The Freetronics Eleven is a direct equivalent of the latest version of the Uno, so when we talk about one we're also talking about the other.

Basically, they're a very compact (69 x 54mm) single-PCB microcomputer based on two Atmel microcontroller chips: an ATmega328P and an ATmega16U2. The 328P device is used as the module's main CPU, while the 16U2 is used to handle communication with the laptop via the module's USB port.

There's not much else, apart from a few low-level chips used for power control and regulation.

Inside the 328P there's a reasonably fast 8-bit RISC processor with 32 8-bit working registers, 32K bytes of flash memory, 1K bytes of EEPROM and 2K bytes of static RAM. There are also two 8-bit timer/counters, one 16-bit timer/counter, a real-time counter with its own oscillator, six PWM channels, six 10-bit ADC input channels, a programmable serial USART, a master/slave SPI serial interface, an I^2C compatible byte-orientated 2-wire serial interface and an on-chip analog comparator.

The 16U2 device is actually not far behind the 328P in capability, with 16K bytes of self-programmable flash memory, 512 bytes of EEPROM and 512 bytes of internal SRAM. It also provides 8-bit and 16-bit timer/counters, three 8-bit PWM channels, an analog comparator and so on.

More importantly, it provides a full speed USB 2.0 communications module, with a 48MHz PLL (phase-lock loop), 176 bytes of USB DPRAM for endpoint memory allocation, four programmable endpoints and the ability to handle bulk, interrupt and isochronous transfers with a programmable packet size of up to 64 bytes and single or double buffering.

Fig.3 shows the simplified Uno/Eleven configuration. On the right is the 328P CPU, with its 14 digital I/O pins brought out on its right and its six ADC inputs at lower left. It uses a 16MHz crystal for its main clock (on pins 9 & 10), while a tiny reset switch is connected to pin 1 (for emergency use only).

At centre left is the 16U2, with its USB data pins (29 & 30) connected to the corresponding pins on the USB socket. It also uses a 16MHz clock crystal, which forms the reference for

the internal PLL (3 x 16MHz = 48MHz) driving the USB module.

The Uno/Eleven provides a choice of either deriving its power from the laptop via the USB cable or from an external 7-12V DC source via a 2.1mm concentric power socket (at upper left in Fig.3). The latter is used mainly when the Arduino is being used in free-standing applications, ie, not connected to a PC.

In the case of the ECG Sampler circuit, we derive power from the laptop PC via the USB connector.

If you compare the pin header labels of Fig.3 with those at the right and lower right of the main circuit of Fig.1, you'll see how the two parts of the ECG Sampler are interconnected. The shield derives its +5V power via pin 5 of the 8-pin power header and its earth/0V from pins 6 & 7 of the same header (plus pin 7 of the 10-pin digital I/O header).

It provides the amplified ECG signals to pin 1 of the 6-pin Analog Inputs header (A0/ADC0), while S1b's switch rotor connects to pin 8 of the 8-pin digital I/O header (IO7) and LED2 is driven from pin 1 of the digital I/O header (IO8).

When the ECG Sampler is working, the sequence of events is quite straightforward. Before the PC software initiates sampling, it sends a request to the Arduino to report the position of gain switch S1. The Arduino sends back a 1-character response, giving that information.

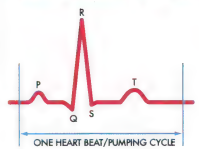
Then, each time the software wants an ECG sample to be taken, it sends a 1-character "take a sample" command to the Arduino, which gets its ADC to take a 10-bit sample of the amplified ECG signal at its ADC0 input. The sample value is then sent back to the laptop, the overall sampling cycle taking less than 4.13ms.

Construction

All the ECG Sampler circuitry, except for the Arduino Uno/Eleven microcontroller board, is mounted on the PCB shield. This is designed to plug into the top of the Arduino board in piggyback fashion. The shield PCB measures 93 x 54mm (only 24mm longer than the Arduino itself, and the same width) and is coded 07108151. The stacked board assembly fits easily inside a standard diecast aluminium box measuring 119 x 93 x 34mm.

The box is used upside down, with

Your Heart & Its Electrical Activity



Most people are aware that the heart is basically a pump which pushes blood around the body via its blood vessel "plumbing" – the arteries and veins.

A typical human adult heart is about the size of a clenched fist and weighs about 300 grams. It's located near the centre of your chest and pumps about once per second, although this can vary widely due to age, fitness, exertion, health etc.

The pumping action is triggered mainly by a nerve centre inside the heart, called the sino-atrial (SA) node. Each pumping cycle is initiated by a nerve impulse which starts at the SA node and spreads downwards through the heart via preset pathways.

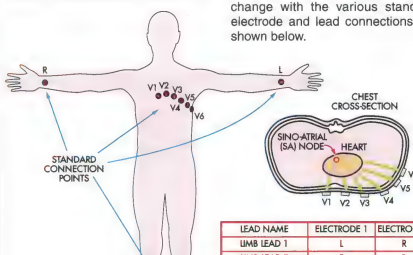
The heart itself is made up of millions of bundles of microscopic muscle cells, which contract when triggered. The muscle cells are electrically polarised, like tiny electrolytic capacitors (positive outside, negative inside), and as the trigger pulse from the SA node passes through them, they depolarise briefly and contract.

With each beat of the heart, a "wave" of depolarisation sweeps from the top of the heart to the bottom. Weak voltages produced by this wave appear on the outside surface of your skin and can be picked up using electrodes strapped to your wrists, ankle and the front of your chest. It's these voltages (about 1mV peak-to-peak) which are captured and recorded as an electrocardiogram or ECG.

The actual shape and amplitude of the ECG waveform depends on the individual being monitored and the positioning of the electrodes but the general waveform is as shown above.

The initial "P" wave is due to the heart's atria (upper input chambers) depolarising, while the relatively larger and narrower "QRS complex" section is due to the much stronger ventricles (lower output chambers) depolarising. Finally, the "T" wave is due to repolarisation of the ventricles, ready for another cycle.

Doctors are able to evaluate a number of heart problems by measuring the timing of these wave components and their relative heights. They can also diagnose problems by comparing the way the wave components change with the various standard electrode and lead connections, as shown below.



LEAD NAME	ELECTRODE 1	ELECTRODE 2
LIMB LEAD I	L	R
LIMB LEAD II	F	R
LIMB LEAD III	F	L
LEAD aVR	R	L + F
LEAD aVL	L	R + F
LEAD aVF	F	R + L
PRECORDIAL (x6)	V1 — V6	R + L + F

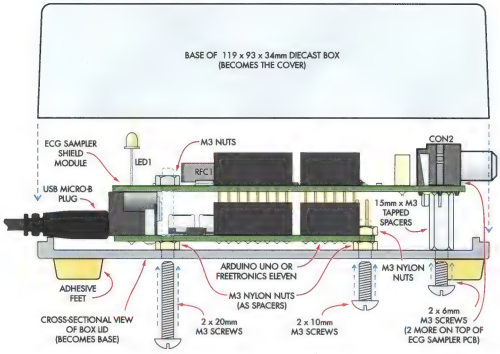


Fig.5: this diagram shows how the Arduino module and the ECG Sampler Shield board are mounted on the lid of the case. Note that the Arduino module sits on M3 Nylon nuts which are used as spacers (do not use metal nuts).

the PCB assembly mounted on the inside of the box lid and the box itself lowered down over the assembly to form a shielded enclosure.

The two RCA connectors (CON1 and CON2) used for the ECG electrode leads are accessed through two 12mm-diameter holes in one end of the box, with miniature toggle switch S1 accessible via a 6.5mm-diameter hole in the same end. The two indicator LEDs protrude up through a pair of 3.5mm holes in the "top" of the box, while a small slot at the far end allows entry of the USB cable.

Most of the components on the ECG Sampler's front-end shield PCB are surface-mount devices, the exceptions being input connectors CON1 and CON2, mini toggle switch S1, the two 1µF MKT input capacitors, the two LEDs and the four SIL headers used for the interconnections to the Arduino module.

Fig.4 shows the parts layout on the shield PCB. We suggest that you fit the SMD resistors first, followed by the SMD capacitors and then the diodes (D1 & D2) and ICs (IC1 & IC2). The main thing to watch with the diodes and ICs is to orientate them correctly, as shown on the overlay.

When these smaller parts have all been fitted, you'll find it quite easy to add the largest SMD component: L1. The leaded/through-hole parts can then be added, taking care to fit CON1 & CON2 so that their moulded spigots pass down through their corresponding holes, thereby ensuring that each connector sits flat against the PCB.

Note that you may need to enlarge the PCB holes to allow this and it may also be necessary to bend up the centre earthing pin of each socket to clear the top of the PCB.

When you're fitting the two LEDs, keep their leads quite straight and position each LED so that the underside of its body is 10mm above the top of the PCB. A 10mm-wide cardboard spacer inserted between their leads can be used to ensure that the LEDs are soldered in at the correct height.

Finally, the four interconnecting SIL headers can be added. These mount on the top of the PCB with their pins passing down through it and soldered underneath. Make sure you don't apply too much solder to the pins themselves though, because they will need to mate with the SIL sockets on each side of the Arduino board.

That completes the shield PCB assembly. It can now be placed to one side while you drill and cut the metal box.

Preparing the box

There aren't very many holes to be drilled in the aluminium case but they must be accurately positioned so that the PCB assembly will fit without problems. We've prepared a drilling and cutting template for the case and this diagram can be downloaded in PDF format from the SILICON CHIP website and printed out. It can then be attached to the case and the holes drilled.

Note that it's best to use a small (eg, 1mm) pilot drill to start the holes to ensure accurate positioning. The 6.5mm and 12mm-diameter holes in one end of the box can be initially drilled out to 4mm and then carefully enlarged to size using a tapered reamer. The square cut-out at the other end of the box can be made by drilling a series of small holes around the inside perimeter, then knocking out the piece and filing the job to a smooth finish.

Mounting the modules

Once the box has been prepared, you're ready for the final assembly. This mainly involves mounting the two PCB modules on the inside of the box lid but this needs to be done in a particular order.

Fig.5 shows how it all goes together. Just follow this assembly diagram and the internal photos and you shouldn't have any problems.

Begin by attaching M3 x 15mm tapped spacers to the two holes spaced 18mm apart at one end of the lid. These should be secured using M3 x 6mm machine screws, as shown in Fig.5.

That done, feed M3 x 10mm machine screws through the next pair of holes (spaced 28mm apart) and fit an

M3 Nylon hex nut on each of these screws. These Nylon nuts act as short spacers, to position the Arduino PCB just clear of the lid.

Similarly, feed M3 x 20mm M3 machine screws through the final two holes in the lid (spaced 48mm apart) and fit these with M3 Nylon hex nuts as well, again to act as short spacers for the Arduino module.

The next step is to turn the Arduino module upside down and check that the mounting lugs on its 2.1mm power connector don't protrude down from the underside of the PCB by more than about 1.5mm. If they do, trim them back using a pair of sharp side cutters. This is necessary to ensure that they don't contact with the metal lid when the Arduino module is mounted in position.

Once that had been done, plug the USB cable's micro-B plug into the matching socket on the Arduino module. The module can then be fitted to the four mounting screws on the lid, so that it rests on the four Nylon nut spacers. A pair of Nylon nuts can then be fitted to the shorter mounting screws at one end of the module to secure it in place.

You won't be able to fit nuts on the two longer screws though, because there isn't room on the Arduino module for this to be done. Instead, this end of the assembly is secured later.

The next step is to plug the ECG Sampler Shield PCB into the Arduino board, as shown in Fig.5. Make sure that all the SIL header pins go into the SIL socket holes on the Arduino. Make sure also that the mounting holes at the "LEDs end" of the shield PCB go over the two M3 x 20mm mounting screws.

Push the shield PCB down until its input end rests on the two 15mm spacers. The other end (the LEDs end) should rest on top of the 2.1mm DC power socket. Once it's in position, attach a pair of M3 hex nuts to the M3 x 20mm mounting screws, to hold both PCBs in place.

The final step is to use another pair of M3 x 6mm machine screws to fasten the input end of the shield PCB to the two M3 x 15mm spacers. **It's a good idea to fit a small star lockwasher under the screw between CON1 and CON2, to make sure that the screw makes a good electrical connection with the earth copper of the PCB.** This connection is used to connect the metal case to the PCB earth, for proper shielding. Both screws should be firmly tightened.

Fig.5: the photo at top shows the Arduino module (a Freetronics Eleven has been used) mounted on the case lid, while immediately above is the completed assembly with the shield board plugged in and secured in place.

Final assembly

Once the lid assembly has been completed, it can be fitted into the case. That's done by first tilting it at an angle of about 20° at the RCA connector end, then lowering it into position so that these connectors and switch S1 pass through their respective holes in the case. The other end can then be lowered into position, at the same time making sure that the two LEDs on the shield PCB go through their 3.5mm holes in the base (which becomes the top).

It's then simply a matter of screwing the cover and lid together using the four supplied countersunk-head M4 screws.

Front panel

The front panel artwork is available for download as a PDF file from the Silicon Chip website. You can then

Dataflex/Datapol Labels

(1) For Dataflex labels, go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335
(2) For Datapol labels go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

This view shows the completed unit with the front-panel label fitted. The electrode leads are terminated in RCA connectors.

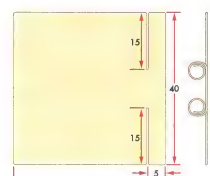


Fig.6: the electrodes are made using 40 x 40mm pieces of 0.15mm thick brass shim (see text).

either print it out and hot-laminate it to protect against scratches and finger grease or you can print out a synthetic Dataflex or Datapol self-adhesive label (see above panel).

Once you have the label, cut out the holes for the LEDs with a hobby knife and then attach it to the case. You can attach a laminated label using either double-sided tape or silicone adhesive.

It's also a good idea to fit four small self-adhesive rubber or plastic feet to the box lid (which becomes the base), so that the heads of the PCB mounting screws cannot scratch any surface the unit is placed on.

Electrode leads

Although it's easy to obtain commercial ECG electrodes at relatively low cost, this doesn't seem to be the case with electrode leads. So regardless of which type of electrodes you use, the simplest approach is to make up a pair of leads yourself.

For this, we suggest you use a 3m length of reasonable-quality figure-8 stereo audio cable – the kind with a decent earth braid around each of the two centre conductors. Don't use "el cheapo" ready-made stereo leads, because many of them don't provide adequate shielding.

The first step is to split the figure-8 cable apart over a distance of about 120mm at one end and fit each lead with an insulated RCA plug. The other end of the cable is then split over a distance of about 1.5m and the leads connected to the ECG electrodes.

The simplest approach is to fit the electrode ends of the cable with small insulated crocodile clips. That's because this type of clip is the easiest way to connect commercial ECG electrodes, which all seem to be fitted with a small metal contact stud. Presumably, commercial electrode leads have a matching clip for these studs but small crocodile clips make a good substitute.

When you're fitting these clips to the lead ends, strip back the cable's outer sleeve and the earth braid wires by about 15mm from the end, then fit a 25mm length of heatshrink sleeving so that the shield braid cannot make contact with anything. Only the centre conductor is soldered to the rear of the crocodile clip and you will need to remove not more than 5mm of the inner dielectric insulation before doing this.

The electrodes

Although you can use the adhesive electrode pads sold in pharmacies for use with TENS machines, these are generally rather expensive. Adhesive ECG electrode pads are also available via a number of suppliers on eBay and these come at a much more reasonable cost. However, when we tried these electrodes, they didn't seem to give a reliable low-resistance skin connection, resulting in a surprisingly high level of hum pick-up.

In practice, we found that we could get much better results using a pair of simple home-made electrodes, each made from a 40 x 40mm piece of 0.15mm brass shim. Fig.6 shows the details. Use tin snips to trim the shims to size, then make two 15mm-long cuts along one side of each one, leaving a 10mm space between the two cuts in the centre.

Next, bend the two ends of the 15 x 5mm strips up and towards each other, to form a pair of loops as shown in the diagram. These loops then make convenient attachment points for the alligator clip at the end of each lead.

Before they're used, be sure to snip off each corner and smooth the edges with a small file and/or fine garnet paper, so they won't scratch the skin. And that's it – they are simple to make

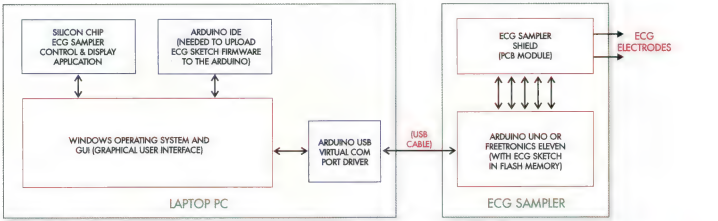


Fig.7: the software block diagram. The large box on the left represents a laptop PC running Windows XP/SP3 or later, while the ECG Sampler unit is shown at right. Follow the instructions in the text to install the software.

and they work extremely well.

Before each electrode is applied to an ankle or wrist, or any other part of the human anatomy, both the underside of the electrode and the surface of the skin should be well moistened with saline solution, to ensure that a good low-resistance contact is made. If you don't do this, you'll see a lot of hum in the ECG traces.

So how do you hold the electrodes firmly (but not-too-firmly) against the subject's skin? The answer is two simple adjustable straps, each made from a 250mm length of 20mm wide Velcro felt strip, along with a 50mm length of the matching hook-strip affixed to the back of one end of each strip.

In practice, each strap is run around the subject's forearm or ankle and over its electrode, before being pulled reasonably tight to hold the electrode in place. It's simple but it works surprisingly well.

Installing the software

As mentioned earlier, there are a number of software items that need to be installed on your laptop in order to use it to take ECG samples. In addition, a software "sketch" has to be uploaded to the Arduino in the ECG Sampler so that it can carry out its tasks.

Fig.7 shows the software block diagram. The large box on the left represents a laptop PC, with its Windows XP/SP3 or later operating system and GUI shown at lower left. The ECG Sampler is shown on the right, linked to the laptop via a USB cable.

The ECG Sampler Application (upper left of Fig.7) needs to be installed on the laptop, together with a virtual COM port driver (lower right, in the PC box) to allow it to communicate with the Arduino module. These are the two main items of software required in the laptop for the ECG Sampler to run.

However, there's another item of software which needs to be installed on your laptop, at least temporarily: the Arduino IDE. This is needed so that you can upload the ECG Sampler sketch to the Arduino.

We suggest that you download and install this software in the following order:

(1) Download the Arduino IDE from the main Arduino website at https://www.arduino.cc/en/Main/Software We used the **1.6.5-r2-windows.exe** version of the IDE but there may be a later version available by the time you read this. There's also a zipped-up version.

When you download and install the Arduino IDE, it comes with a USB virtual COM port driver to suit the Arduino Uno. This is installed in the ***/Drivers*** folder of the IDE installation. As a result, if you are using an Arduino Uno in your ECG Sampler, you'll already have its matching USB port driver.

Alternatively, if you're using a Freetronics Eleven, you will have to download the matching USB driver from http://www.freetronics.com.au At the time of writing, this was in a zip file named **FreetronicsUSBDrivers_v2.2.zip**. After downloading it, unzip it into a folder so that it's ready for installation – see below.

(2) Plug the cable from your ECG Sampler into one of the USB ports on your laptop. The ECG Sampler's power LED should immediately light but the Windows OS will probably flag a problem, indicating an error when it tried to install the driver for this "new and unknown" device. Even if this doesn't happen, you still have to install the correct driver, though.

(3) Go to Control Panel on the laptop and then to Device Manager. This will show an error icon alongside an "Unknown device" listing. If you right-click this item and open Properties, you'll see that the problem lies with the driver for the device – it's either not properly working or not installed at all.

To install the driver, click on the "Driver" tab, select "Update Driver" and then click "Browse my computer for driver software". You then browse to either the /Drivers folder of your Arduino IDE installation (to get Arduino's Uno driver) or to the folder where you unzipped the Freetronics driver (to get the Freetronics Eleven driver).

In either case, you should be able to see the **.inf** file that Windows needs to install the new USB driver. When you return to the Device Manager, Windows should be able to install the driver and you should then see the "This device is working properly" message.

SAFETY WARNING

To ensure complete safety, this ECG Sampler should be only used with a battery-powered laptop PC; ie, one that's NOT connected to the mains via its charger. Do NOT use it with a desktop or laptop PC that's connected to 230VAC.

This precaution is necessary to eliminate the remote possibility that a fault in the power supply of a mains-powered PC could result in a high AC voltage being applied to the electrodes.

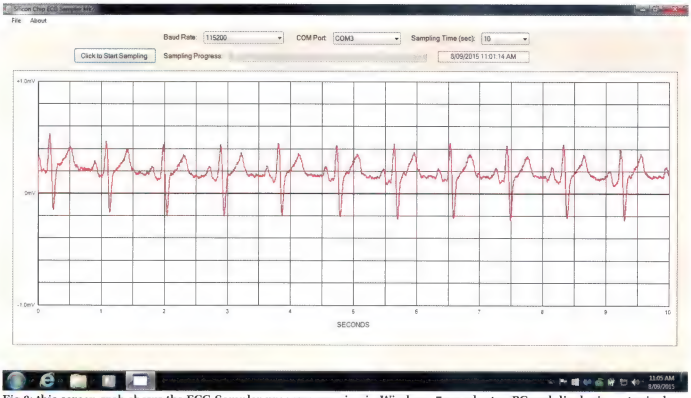


Fig.8: this screen grab shows the ECG Sampler program running in Windows 7 on a laptop PC and displaying a typical ECG waveform. The tiny regular oscillatory noise component in each cycle is residual 50Hz hum.

(4) Point your web browser to www.siliconchip.com.au and download both the Windows software for the ECG Sampler (**SiliconChipECGSamplerSetup.zip**) and the matching Arduino firmware sketch (**sketch_for_ECGSampler.ino**). These files should be saved in your */**Documents*** folder, in a sub-folder called */**Arduino sketches***.

(5) Launch the Arduino IDE and direct it to that sub-folder to find the sketch. Open this and upload it to the flash memory in your ECG Sampler's Arduino (you'll find this process is quite straightforward).

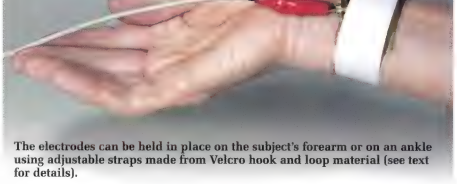
(6) Finally, unzip the **SiliconChipECGSamplerSetup.zip** file and double-click the **.msi** file to install our Windows ECG Sampler application. That's it – you should now be ready to roll with your new ECG Sampler.

Taking an ECG

Apart from the Sampler's gain switch, which is set to either LOW (1000) or HIGH (2000), all functions of the USB/ECG Sampler are controlled using the ECG Sampler program. This is easy to use because when you fire it up, it provides a GUI window (see Fig.8) which provides combo-box buttons along the top so you can set the sampling configuration: the Baud rate to be used (115,200) for communication with the Sampler, the COM port it's connected to (usually either COM3 or COM4) and the sampling time you want (5, 10 or 20 seconds).

You then start an ECG recording simply by clicking on the "Start Sampling" button. The software then shows a progress bar at the top of the application window and a sample plot display which "grows" in the accompanying graph graticule.

As shown on Fig.8, there are two drop-down menus at the top, with the familiar labels "File" and "About". As usual, the first menu gives you options for saving, reloading and printing your ECG recordings, plus an option to close the application when you're finished. The "About" menu item simply brings up a small dialog box which shows the version number of the software.



The electrodes can be held in place on the subject's forearm or on an ankle using adjustable straps made from Velcro hook and loop material (see text for details).

Lead configurations

Finally, which lead configuration should you use, just to take a basic look at your own ECG or that of someone else?

Our recommendation is that you use the "Lead II" limb configuration, with lead 1 connected to the subject's left

Parts List

1 PCB, code 07108151, 93 x 53mm
1 set of Arduino stackable shield headers (1 x 10 pin, 2 x 8 pin, 1 x 6 pin)
1 diecast aluminium box, 119 x 93 x 34mm
1 Arduino Uno or Freetronics Eleven module
1 USB cable, type A to micro-B connectors
2 RCA sockets, PCB-mount (CON1,2)
1 100µH 1.6A SMD inductor (L1), Murata 48101SC (element14 2112367)
1 miniature DPDT toggle switch, PCB-mount (S1)
2 M3 x 15mm tapped spacers
4 M3 x 6mm machine screws (round head)
2 M3 x 10mm machine screws (round head)
2 M3 x 20mm machine screws (round head)
6 M3 Nylon hex nuts
1 M3 metal hex nut
4 adhesive rubber/plastic mounting feet, small

ECG electrode parts

2 insulated RCA plugs
3 metres of figure-8 shielded stereo cable
2 40 x 40mm squares of 0.15mm brass shim (see text)
2 32mm insulated alligator clips (one red, one black)
2 50mm lengths of 20mm wide Velcro hook strip
2 250mm lengths of 20mm wide Velcro felt strip
2 25mm lengths of 4mm diameter heatshrink sleeving

Semiconductors

1 AD623ARZ instrumentation op amp, SOIC-8 package (IC1)
1 NE5532D dual op-amp, SOIC-8 package (IC2)
1 3mm green LED (LED1)
1 3mm red LED (LED2)
2 1N5711W7F Schottky diodes, SOD-123 package (D1,D2)

Capacitors (1206 SMD)

4 100µF 6.3V X5R ceramic
1 10µF 6.3V X5R ceramic
1 6.8µF 16V X7R ceramic
2 1.0µF 5% 100V MKT (leaded)
2 1.0µF 16V X7R ceramic
3 100nF 16V X7R ceramic
1 47nF 50V X7R ceramic
2 1nF 1% 50V C0G ceramic

Resistors (0.125W, 1%, 1206 SMD)

2 2.2MΩ	1 2.7kΩ
2 20kΩ	1 2.2kΩ
1 11kΩ	1 1.2kΩ
1 10kΩ	2 470Ω
2 4.7kΩ 0.1%	1 100Ω
2 3.0kΩ	1 82Ω

ankle and lead 2 connected to their right wrist or inside forearm. This usually gives the largest waveform amplitude, providing your electrode-skin connections are good.

If you get weak waveforms with a relatively large amount of hum, this is usually a sign of poor electrode contact. So take them off, apply a bit more saline solution and try again.

The exact positioning of the limb electrodes is not critical, as the limbs are really just being used as convenient conductors joined to the four "corners" of the subject's trunk. The most important thing is to get the best possible contact to the skin.

If you want to try some of the chest positions for the lead 1 electrode, the electrode positions are then fairly critical. You really need to have some medical background to know the right chest electrode positions, so it's best to leave this to the professionals.

Note that if lead 1 is used with a chest electrode, lead 2 should be connected to electrodes in all three of the limb positions so that it provides a "whole body" reference signal. In practice, this means that you'll need to make up at least two more electrodes and connect them in parallel with the original lead 2 electrode. That's done by connecting the additional electrodes to the ECG Sampler's CON2 input socket via leads that are the same lengths as the original leads.

If you really want to play around with all the lead configurations, you might want to make up a set of nine electrodes and leads, plus a small switch box to allow you to select any of the standard lead configurations (see diagram on page 59) at will. SC

Which one do you want?

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SERVICEMAN'S LOG

Putting on the deer-stalker

Dave Thompson*

Persistence often pays off in the service business but not always. Knowing when to pull the pin on a job can be just as important as knowing when to put on the deer-stalker and play detective. As Dirty Harry said, "a man's got to know his limitations".

ONE ASPECT of service work that all servicemen encounter from time to time is the need to play detective. What I mean by this is that, every now and then, we need to put on our deer-stalker hat and really investigate in order to get to the bottom of whatever it is we have encountered.

This detective work can relate to any aspect of the job, from discovering exactly what is wrong to identifying the parts used in the device. It can even extend to tracking down those parts once we know what they are. This process sometimes stretches our skills and tests our "outside-the-box" thinking but the rewards are the satisfaction of a job well done. Such jobs are often also a welcome break from the sometimes monotonous routine of bread and butter service work.

Troubleshooting is one of those skills crucial to any serviceman and in my opinion is a talent one either has or doesn't have. It is very difficult to teach troubleshooting to someone who has no aptitude for it and while this could possibly be done, in my experience people tend to fall into the two camps: those who can troubleshoot and those who can't.

A serviceman trying to discover what is wrong with a job is much like a detective solving a crime. The "view out the window" might be quite different but the methodology is similar in that we use whatever clues we can glean from the job itself and from the people involved in order to get us started in the right direction.

Items Covered This Month

- Digital AM/FM radio
- Yamaha T-520 tuner
- A tale of two Topfield PVRs
- Samsung PS43D450 plasma TV

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Of course, not all jobs that go through the workshop require this sort of detail. For example, if a computer comes in with an electrical smell and it won't power up, I (and other technicians) would immediately assume a power supply issue and start with that, testing it and perhaps swapping it out to confirm the diagnosis. And in most cases, that would solve the problem.

Despite this simple approach though, basic troubleshooting methods have still been followed to reach a conclusion. But because I've experienced the fault before, I already know where to start and what direction to take.

However, every now and then I get a job that exhibits symptoms I haven't encountered before. What's more, the owner's description of what's gone wrong is of no use in identifying a starting point for the troubleshooting process. In such cases, I default to what I do know and work my way forward from there and that's just the sort of situation where a serviceman's troubleshooting/detective skills really pay off.

An added complication is the pressure of the job. Those of us who work as servicemen usually have time-sensitive aspects to our work. Basically, we are expected to repair items as quickly,

~EVERY NOW & THEN, WE NEED TO PUT ON OUR DEER STALKER HAT AND REALLY INVESTIGATE

accurately and professionally as possible, while maintaining profitability and a good reputation for the business. And let's not forget the customer, who is waiting for the device to be repaired and returned as quickly as possible so that they can carry on with whatever it is they need to be doing.

Because of this, we often don't have the luxury of a trial-and-error style of repair. Instead, we rely on experience and skill to quickly narrow down what could be wrong and resolve it in the shortest possible time. If we can do this, we maximise our earning potential and the fast turnaround enhances our credibility in the eyes of the client.

Unfortunately, it sometimes doesn't work out that way. I imagine many servicemen can recall jobs where they couldn't possibly invoice all their otherwise chargeable hours because the cost of the job would end up being ridiculous and the customer simply wouldn't wear it. But while we all have to deal with such jobs every now and then, the better our experience and troubleshooting skills, the less this type of scenario crops up.

This is also why when I'm hiring technicians, the people with the most workshop experience don't necessarily get hired. Instead, I also look for people with natural troubleshooting skills because given the repetitive nature of our work, any competent person soon picks up the technical aspects of the job. I certainly don't have the time or inclination to try to teach troubleshooting to someone who hasn't a natural talent for it.

Digital AM/FM radio

So what's all this leading to? Well, I recently had a brand new, digitally-controlled AM/FM radio come into the workshop and it really tested my skills.

First, I had to determine if it was worth repairing. My customer offered up his suspicions that he had fried this newly-imported radio by powering it up with the included "wall wart" power supply which, as it turned out, had been designed for the US market and their 110-120VAC mains. When he had plugged it in here in NZ and hit the power button, a wisp of smoke and an electrical burning smell immediately let him know that something had gone wrong.

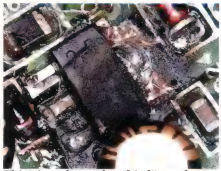
This was a particularly cruel outcome for my client because he'd spent a lot of time researching on-line before deciding to import this particular radio. What's more, as an electronics hobbyist, he knew that he'd possibly done irreparable damage to the set. Nevertheless, he hoped that, if the gods were smiling, I could replace any blown components and get it working again. I really hoped that I could too!

As always, even though my client had explained what he thought he'd done, I started at the beginning and checked things out while keeping his suggestions in mind. I got the impression he was annoyed at himself for not noticing the voltage ratings on the supply and I really wanted to get a good result for him because I had been there and done that myself. In fact, if the truth be told, I've done it more than once!

Right from the start, I knew that this job would be challenging. As is typical with many commercial electronic products, a Google search proved that service documentation for the radio, in the form of schematics or circuit diagrams, was virtually unobtainable. I did have the user manual that came with the radio but it was useless for anything but setting the thing up once it was powered up.

Given that it was a well-known brand, I thought there would be at least some information on it floating around the web but I was wrong. However, I did find some workshop manuals for radios from the same manufacturer that were previous to this model and so I downloaded those. Many manufacturers reuse circuitry or designs from one model to the next and having some circuits is better (in most cases) than having no circuits at all.

Like most modern electronic devices, this radio almost exclusively uses surface-mount components. Of course, parts like the ferrite-rod antenna coil and some capacitors cannot be reduced in size in the same way as a transistor or resistor. The other parts though were all basically just tiny black specks covering the two double-sided circuit boards that made up the inner workings of the radio.



This view shows the "fried" regulator inside the radio. The numbers "2" & "5" were just barely visible.

After removing six PK screws and cracking the radio's case, tracking down where the fault actually lay didn't take long. I already knew what had caused the problem so it was just a matter of following the tracks from the power socket inwards into the rest of the circuitry until I found where it had all come to grief. It wasn't hard to spot – the scorch marks on the board and on the inside of the case made the affected area stick out like a lump of coal in snow.

The two halves of the case were tethered by several flying leads going from the circuit boards to the antenna, speaker and battery holder so I desoldered these in order to separate the two halves and make access easier. Once I had it apart, I took a closer look. Fortunately, I'd recently purchased one of those 500x "USB Microscopes" that I'd seen advertised in a catalog. While nowhere near laboratory quality, this unit, which is essentially just a reasonable-quality camera with a manual telescoping lens, is more than adequate for getting up-close and personal with circuit boards.

Indeed, with its built-in LED lighting and provision for taking snapshots, this USB microscope is very handy for finding miniscule physical faults, especially as everything is so tiny these days. It has made me less reliant on my trusty magnifying headset and I'd recommend one to anybody doing this (or any other) type of close work and who has trouble seeing small components.

As mentioned, locating the physical fault was easy; the real detective work started when it came to identifying exactly what the component had been before it had disintegrated when too much current went through it. All I could tell initially was that this used to be either an SOT-223 or SOT-89 component.

Under the microscope, I could make out the number "2" on the surface of the component and what was possibly a "5" printed next to it. These numbers were rotated 90° when the component was viewed "normally" – ie, when viewed with its tab at the top and its three leads at the bottom, the number lay on its side towards the lefthand edge. This meant that it was highly likely that there were other numbers printed alongside the "2" and the possible "5" but these characters, if indeed they did previously exist, were now illegible (see photo).

I tried various tricks I'd picked up over years when working with old transistors, capacitors and ICs to make the markings legible but nothing worked. For example, huffing on it with a bit of breath "fog" sometimes makes things readable but that didn't work here. Similarly, wetting the device with a tiny sponge or applying various sprays such as freezer, CRC and contact cleaners can sometimes create enough contrast to see what's hidden there but these techniques also failed in this instance

By the way, I only apply the latter when the other methods don't work, just in case the spray actually washes the numbers away even more.

Finally, in desperation, I tried using my fibreglass-bristle PCB brush to very gently scuff away at the charred remains of the component's plastic case. I must admit that I felt rather like an archaeologist revealing hieroglyphics on some ancient artefact during this process but my efforts paid off. Amazingly, the process was partially successful and resulted in me uncovering the top of what looked like a "H" or a "U" or possibly an "N".

Of course, this might not have meant anything significant but every little bit of information can be a clue when it comes to identifying such parts.

It wasn't much to go on but I hit the web and looked for SOT-223 and SOT-89 devices with "2" and "5" in their codes. Unfortunately, most pages I found didn't refer to anything with a "2" and a "5" on it, so I had to dig even deeper, utilising image searches as well in case I stumbled onto something. I wasn't overly hopeful though, as there were too many variables.

Eventually, I found some SOT-223 packaged NPN transistors with various codes beginning with "2" but after studying the datasheets, I figured out that I should be looking for a SOT-89 device due to the size difference between the two. Not having had a lot of experience with SOT components hampered me in this case but one has to learn somewhere.

With that established, I concentrated on references to SOT-89 packaged components and eventually found some voltage regulators that used "2 5" codes – specifically low-dropout voltage versions. In all cases, the remainder of the code specified the value of the component but to my frustration, there was nothing alongside the letters I'd uncovered with my careful brushing.

By now, I'd already spent a couple of hours on this parts search. And it was fast becoming apparent that this was going to be one of those jobs with non-chargeable hours, along the lines mentioned earlier.

My next step was to refer to the service manuals I'd downloaded for other model radios from the same manufacturer. The burned-out device was mounted adjacent to the LCD module and I knew that it was something to do with the power supply. My hope was that a similar arrangement had been used on one of those other circuits.

There were many transistors in SOT-23 packages in these older circuits but these were smaller than the component I was looking for and could be discounted. Eventually though, my

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

persistence paid off. On two of those earlier models, there was an SOT-89 device positioned near the display and the surrounding circuit in each case was very similar (but not identical) to the circuitry I'd traced out on the faulty radio. Finally, I felt as though I was onto something.

When I looked up the parts list in the service manuals, both specified the same 5V, low-dropout voltage regulator. This carried a 2 5 7 G number, which (basically) coincided with what I had deduced from my parts search.

Convinced I'd found what I needed, I promptly ordered a couple (at a massive $3.95 each) and prepared for the next phase of the operation – removing the wreckage from the board and preparing it for the new component.

Sadly, removing the old component proved all too easy. As I attempted to de-solder it, its body simply crumbled away, revealing a deep crater in the board. Several adjacent PCB tracks were also gone and that meant that even if I'd gotten lucky with the replacement component, I now had to try to match up the regulator's leads with whatever tracks I could trace out from the mess on the circuit board.

The top tab and the middle lead would both be grounds and the input lead sat very near a partial track to which it likely should be connected. However, the output lead sat in a bare area of PCB with nothing within 5mm. Certainly, there were no tracks that looked like they were meant to be connected to this device.

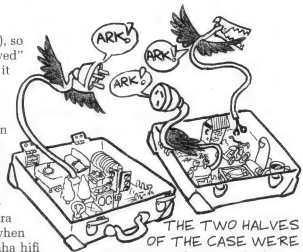
All I could do initially was solder in the other leads as best I could. Then, after referring to the other circuit diagrams, I applied power from my current-limited bench supply, switched the radio on and carefully tried touching each potential nearby track with a flying lead I'd soldered to the regulator's output lead.

Unfortunately, nothing lit up and at that point I threw in the towel. While I was fairly sure I'd tracked down the correct part, even if I'd wired it in correctly, there was a good possibility that other components had fried. Troubleshooting this device any further would take far too long considering what I would ultimately be able to charge for the job.

A good serviceman knows when to pull the pin and, in hindsight, I should have pulled the pin on this one some time ago. Instead, I'd persisted and run out of steam (and options), so this one goes in the "unsolved" file. I'll just have to put it down to experience.

Yamaha T-520 tuner

Tracking down faults in electronic equipment can be quite difficult, if not impossible, without a service manual. Fortunately, T. I. Penguin, Tasmania outlayed some extra cash for service manuals when he purchased some Yamaha hifi gear nearly 30 years ago . . .



In 1986, I purchased a Yamaha A720 100W stereo amplifier and a matching T-520 AM/FM tuner for a total cost of $1000. I agreed to purchase these Yamaha units on the condition that the salesman also include the service manuals for the two units which, after some haggling, he reluctantly agreed to do. They did, however, cost me an extra $12 if I remember correctly.

At the time, I filed the manuals away in a drawer somewhere and as the years slipped by, I eventually forgot about them. Apart from having to replace a noisy volume control pot in the amplifier, both units have operated flawlessly until fairly recently, so I'd had no need to refer to the service manuals.

The tuner is a good-quality stereo PLL (phase locked loop) unit with a LED frequency display and eight programmable station presets for the AM and FM bands. Normally, when the tuner was switched on, the last-used preset station would be selected until one day, for some unknown reason, it suddenly lost all its presets. I went through the process of reprogramming all eight stations and then power-cycled the unit to see if the problem reappeared but it all worked normally, so I left it at that for the time being.

Several days later, I switched the tuner on again, only to find that the station presets had again been lost. This became a pattern until eventually the reprogrammed presets were being lost immediately when the power was switched off.

By now, I was beginning to think that perhaps an on-board battery that was used to retain power to a memory chip had failed. Or maybe it was the memory chip itself that was at fault. That left me wondering where I could obtain the circuit for this aging tuner when I suddenly remembered paying the extra cash for those service manuals all those years ago.

Rifling through some drawers and files soon turned up the required manual and this showed that the tuner has one main PCB for most of the functions, including the AM and FM tuning, PLL and programming sections. It also has five smaller satellite boards for the readout, station preset buttons, power supply and voltage selection etc.

After studying the circuit, I could see that the control and programming functions were carried out by IC105. This is a 42-pin LC7030 "Electronic Tuning Controller" IC that's used to control IC104, an LM7000 PLL chip. Pin 40 of IC105 is the V_{DD} (power supply) pin and this is connected to a +6.1V supply rail via diode D110, which should result in close to +5.5V on V_{DD}. Also connected to the V_{DD} pin were three parallelled capacitors: C155 (0.01µF), C157 (10µF) and C156 (47,000µF 5.5V). Given its high value and its location, I wondered if the latter was the culprit.

After unplugging the unit from the power, I proceeded to remove the case by undoing the two screws on either side and sliding it free. I then located C156 on the main PCB but in order to access its connections, I needed to lift the main board clear of the chassis. I undid the several mounting screws and was then able to lift the board high enough to access the copper tracks.

That done, I checked the voltage across C156 with the power still off and it measured slightly less than 0.2V. I then carefully chocked the PCB up on some insulating pads, applied power and checked the voltage across C156

A tale of two Topfield PVRs

B. C. of Dungog, NSW had a bit of luck when he bid on two faulty PVRs on eBay recently. He ended up with both for the price of one and what's more, he got them both going again. Here's what happened . . .

During the latter part of my working life, I tried to avoid the use of computers as much as possible, being a late adopter of this technology. And when analog TV reached its end, I knew that the end had also come for my repair career.

Soon after, we did the tree change thing and moved to a small town close to the east coast. My wife discovered eBay a few years ago but I was initially reluctant to get too involved. However, when it came to technology, it opened up a new world as to what could be bought, both in Australia and overseas.

In the past, I used to go to garage sales and swap meets to get the electronic gadgets that I wanted. However, that's pretty well dried up in recent years and as I soon discovered, eBay and other sites are now the way to go. The internet truly is a marvellous thing.

Recently, I was on the look-out for a newer Topfield HD PVR to replace my faithful old Silver Topfield SD PVR which had finally died with a serious motherboard fault. A quick search on eBay came up with two Topfield PVRs for sale from the same seller, both not working and for spare parts only. They required local pick up and the seller was within a reasonable travelling distance.

As the auction closing time approached, I bid on the SD Masterpiece unit but was pipped at the post. And so, with only a few minutes to spare, I bid on the HD 7100 and this time I was successful.

After picking the unit up, I wasted no time in removing the top cover to see if a resurrection was in order. First, the power supply unit (PSU) was removed and a number of electrolytic capacitors were found to have gone high ESR. It's usual to take a shotgun approach with this particular PSU and replace all the electrolytics with 105° EXR-series electrolytic capacitors for better reliability, so that's what I did. The PSU was then refitted and the PVR was fired up.

I then found that the supplied remote control wouldn't work! I fired up the camera on my mobile phone, aimed the remote control at it and pressed some of the remote's buttons. The resulting red flashes on the screen indicated that the remote itself was working OK so the fault lay elsewhere.

I got back onto eBay for a closer look at the PVR that I had just bought. The one I had was the same size as the one pictured but it looked a little different! It turned out that I had mistakenly been given the Masterpiece SD PVR that I had lost out on at the auction! As a result, I got in contact with the seller and arranged to pick up the HD 7100. When I got there, the seller said that I could keep the SD Masterpiece as the other buyer only wanted the remote control.

The next day, I took the top cover off the HD 7100 PVR and had a look around. The PSU used in this unit had been redesigned and the forest of electrolytic capacitors had been thinned out. I removed the PSU and found that all its electrolytic capacitors passed the ESR test, so it looked like the supply was probably OK.

When I replaced the PSU and fired it up, the PVR went through its initialisation stage and both the display and the HDD started up. However, there was no picture or sound on my test monitor and no sign of the menu display.

Back on the internet, I downloaded the manual for this model and soon again. As expected, it measured 5.5V but I found that as soon as the power was switched off, the voltage across it immediately fell to 0.2V instead of remaining close to 5.5V. This indicated that C156 was faulty and although I wasn't entirely sure, it seemed to me that this could well be the cause of the problem with the presets.

After taking note of its polarity, I carefully removed C156 using some solder wick and soldered a replacement capacitor in. I also thought about replacing C157 since low-value electros can also cause problems but decided I would test the unit first.

I applied power again and and this time, when the power was subsequently removed, the capacitor held most of its charge, dropping only a couple of millivolts over a period of several minutes.

Feeling confident, I fastened the PCB back into position, reassembled the case and programmed in several stations using the preset buttons. I then switched the power off and left it off for several hours. When I subsequently switched the tuner back on, I was pleased to see that all the preset stations were still present. The unit has now performed perfectly for many months.

In hindsight, the $12 I spent on the manuals all those years ago was well worth it. If I hadn't done so, tracking down the fault would have been much more difficult and would have taken a lot longer. I may have even had to junk the unit.

Samsung plasma TV

Falling on a plasma TV set and knocking it to the ground is never a good idea. P. E. of Heathcote, Victoria was the mate who fixed it for his clumsy friend. And he fixed the TV's remote control unit for good measure. Here's what happened . . .

A friend of mine recently gave me his Samsung PS43D450 plasma TV to "have a look at". Whenever I hear that phrase, my first question is "what did you do to it?"

Well, in this case, it was working fine until he fell on it and gravity took over. As it hit the floor, he heard a "pop" and when he righted it, there was no picture or sound.

I said that I'd "have a quick look at it". I didn't initially hold out much hope though because it was quite possible that the plasma panel had been damaged. On the other hand, there was no visible damage to the panel so it was at least worth taking a look inside the set.

I laid the TV face down on a blanket-covered table and immediately

found a reference to the Format button on the remote control. I then cycled the Format button until the Menu screen suddenly appeared. The "Factory Default" setting was then selected and the unit reset, ready for a channel rescan. However, no channels would scan in!

I went back to the internet to see if I could find any further clues as to what the problem might be. After some research, I found a reference to a faulty surface-mount transistor marked "2T". This transistor was located near the twin tuners in an earlier model Topfield PVR and it was well worth taking a look at the parts in that area in my unit.

Armed with a strong magnifier and my trusty DMM, I took a close look at the surface-mount parts near the twin tuners with some trepidation. It was a bit different to the earlier models but there were still some 7805 voltage regulators in that area of the motherboard. Two of these had +5 volts on their outputs but one, designated U5, had no output. Aha!

Further measurements in the area showed that SMT device Q1 (marked 2T) was not switching through the +7.5V rail to the regulator's input. Static tests of this SMT device indicated that it was OK, which meant that it wasn't being switched on by the microcontroller.

In the end, I bridged Q1's collector to its emitter and when the PVR was powered up, the 7805 (U5) now had a +5V output. A channel rescan then filled up the on-screen table with local digital channels and the HD 7100 PVR was back in business. I then replaced the CR2032 lithium back-up cell on the back of the display PCB before replacing the cover and I did the same for the Masterpiece PVR.

All I had to do now was solve the missing remote control problem for the Masterpiece PVR and I would have two working units. Fortunately, I had previously purchased a Logitech Harmony 300 programmable remote control and this unit has got me out of strife on numerous occasions.

And so it was back to the internet! I clicked on the Harmony App and logged into my account. I then followed the instructions and downloaded the correct remote control codes for the Topfield Masterpiece PVR and added the required special functions to the spare pushbuttons.

Success at last – the Masterpiece PVR responded to the Logitech remote control and, with its refurbished PSU, it worked perfectly! I now have a PVR for HD recording and also a PVR for SD recording, when three or four wanted TV programs are on at the same time. It was a bit of luck but I ended up with two PVRs for the price of one!

noted a large dent in its aluminium back. No less than 21 screws needed to be removed, these being a mixture of self-tappers and machine types. There were only six machine screws, so I stuck masking tape adjacent to their locations to make it easy when it later came to reassembly.

With the back off, I could see the problem straight away. Something had hit the aluminium back hard enough to push the PSU (power supply unit) onto an earthed plate. In addition, the PSU's board had a crack about 30mm long and this crack ran through several fine tracks.

Removing the PSU board was easy – just unplug several connectors, remove a few screws and lift it clear. I didn't think that it could be fixed at component level but it was at least worth a try.

I began by repairing the broken tracks by bridging the gaps with solder and then replaced the main electrolytic capacitors. I then reinstalled the PSU, stood the TV up vertically without the back on and applied power. I was greeted with a clicking relay and a flashing red standby LED on the front panel. This LED was repeating a 3-flash fault code but I was unsure as to what exactly this meant.

Oh well, I wasn't surprised. The PSU board measures about 240 x 240mm and carries hundreds of parts, many of them surface mount devices. It's not surprising that some of them had been damaged when my friend fell on the set.

It was time to see if I could track down a replacement PSU board so I "Googled" its part number and found that I could purchase a new one from Latvia(!) for $54 (including postage). I placed an order and the PSU duly arrived two weeks later. It hadn't been packed all that well but it had survived.

Installing it was a simple matter and on switch-on, I was greeted with a "No Aux Input" message on the screen. Changing to the digital TV input immediately brought up Channel 9 so it was all working again.

I left it on for an hour and it all worked perfectly. The rear panel was easy to beat flat with a plastic mallet and it was then just a matter of slipping it back into position and reinstalling all those screws.

That wasn't the end of the job though – the remote control had had coffee spilt on it at some stage and it also had what appeared to be toffee plastered over some of the keys. As might be expected, it didn't work well at all.

TV remotes that clip together are not always easy to take apart but the procedure is similar for most models. This is how I do it: first, the remote is held horizontally in a vice, just above the seam between the top and bottom halves of the case. I then tighten the vice until the plastic starts to flex, after which a sharp flat screwdriver blade is held against the seam and given a sharp tap with a hammer.

Alternatively, if the screwdriver fits into the seam, it can simply be twisted to prise the two halves apart.

If you do this correctly, the remote will pop open on one side and it's then just a matter of doing the same on the other side.

Having opened the remote, the PCB was removed and the plastic case sections and the rubber keys washed in warm, soapy water. The PCB was then cleaned using methylated spirits (not water), after which all parts were gently dried with compressed air. As is my usual practice, I then smeared a tiny amount of WD40 on the copper side of the PCB.

After that, it was simply a matter of reinstalling the parts and clipping the case back together. The main thing to watch out for here is that the battery terminals line up with the rear plastic body. I then checked the batteries and gave the unit a test run. All functions worked except for one that seemed unimportant, so I left it at that.

As it turned out, the function that didn't work wasn't used. And the cost to my mate? – $54 plus two meals at the pub! SC

Build this 5-Element Yagi Antenna for better FM reception

By LEO SIMPSON

What's your FM reception like? Pretty poor? Does the music sound distorted or are there lots of sibilants on voice? If so, you need a proper FM antenna, not a bit of wire hanging out the back of your tuner. But they're not real easy to buy these days! So why not build your own? This 5-element Yagi antenna is designed specifically for the FM band. You'll be amazed at how good those stations can sound when they have a strong signal.

These days, many people are listening to DAB+ broadcasts and we can well understand why. There are more stations and provided the signal is OK, the sound will be OK too. But it will only be "OK" to the extent that the sampling rates used by virtually all DAB+ stations are barely adequate to give good sound quality.

Yes, yes, we know that many people now listening to internet streaming services and they have thousands of music stations from around the world to choose from but again, the sound quality is just average.

If you want really good broadcast sound quality, FM stations cannot be bettered. Of course, if you live outside the capital cities, there is no DAB+ and so it's FM or nothing if you want to listen to music broadcasts with good sound quality.

And if you *are* outside the major cities you are going to need a good FM antenna to get the best sound quality – nothing else will do. Of course, living in a large city, probably with hilly surrounds and tall buildings can still mean that you will get weak signals and "multipath" reception.

This is the same effect as "ghosting" on TV. Multipath causes bad distortion and you can only cure it with a good antenna.

So what FM antenna should you buy? They are virtually unavailable. This was the situation when we originally presented this antenna design back in October 1988 and repeated in March 1998. Things have not improved since then and we still get asked for a good FM antenna. So we are presenting it again, with very slight changes.

The antenna is a 5-element Yagi array. It has a folded dipole, a single reflector and three directors. It has an estimated gain of between +8dB and +9dB with respect to a dipole and an improved front-to-back ratio compared to a 3-element array, the most common FM antenna in the past.

By the way, if you have an old VHF TV log periodic array it *could* be pressed into service but it won't perform quite as well as this antenna which is cut to suit just the FM band from 88 to 108MHz.

Narrow acceptance angle

As well as a good front-to-back ratio, this antenna is also quite directional – or to put it another way, it has a narrow acceptance angle. Both of these factors mean that reflected signals coming in from the sides and rear of the antenna will be suppressed. This is worthwhile because the more suppression you can obtain for reflected signals, the less

5-ELEMENT FM BROADCAST ANTENNA

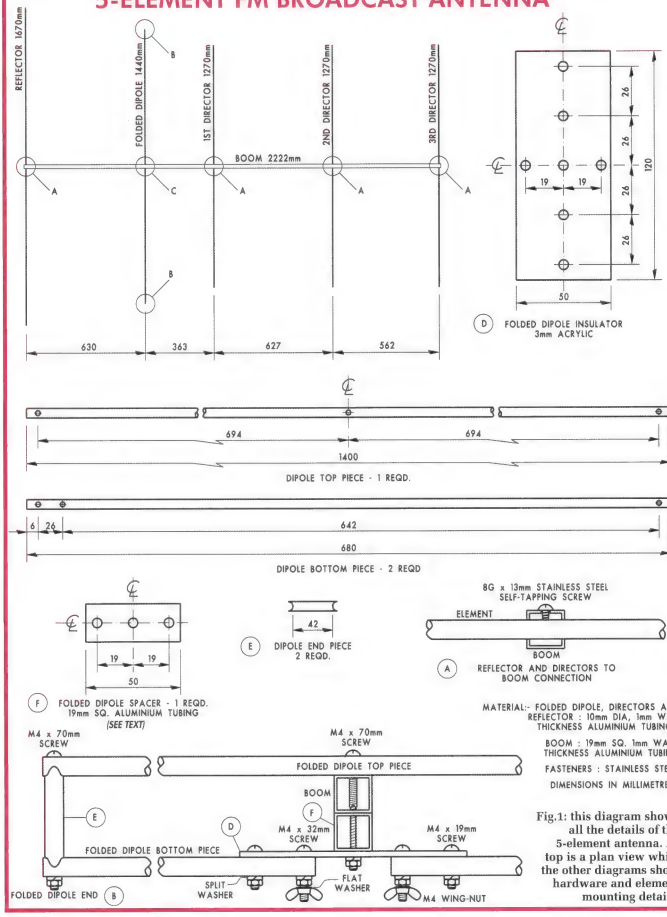


Fig.1: this diagram shows all the details of the 5-element antenna. At top is a plan view while the other diagrams show hardware and element mounting details.

This shot shows the fixing of the dipole top element to the boom and plate. This is done with a 70mm long stainless steel screw which passes through the top element, then the boom and spacers below to the Lexan plate.

The dipole insulator plate has wing nut terminals to connect 300Ω ribbon or a 300Ω-to-75Ω balun. The plate is made from Perspex, Lexan or other acrylic material. The square boom makes mounting easy.

distorted the resulting stereo sound will be.

We're talking here about "multi-path" reception, which used to plague analog TV reception and cause ghosts in the picture. With FM broadcasts, multi-path reception causes the sound to spit and sputter, especially if a low-flying plane passes overhead.

Apart from reducing multipath problems, the big reason to build this antenna is to obtain lots more signal than you would get from a random piece of wire or the common twin-lead dipole wire antenna that is supplied with many tuners. Furthermore, because it will be installed outside your home, the signal pickup will be even better. In fact, our observations show that with a good FM antenna such as this, it is possible to pick up stations (in stereo) which may be more than 160km away.

Finally, by feeding more signal to your tuner, even from your strong local stations, you will improve the reception and it will be less susceptible to interference from equipment with switchmode power supplies. There will be less distortion, better separation between channels and less hiss in the background.

Tools you will need

Most enthusiasts will have all the tools needed for this project: a hacksaw, electric drill and a vice. It would also help if you have a drill press but you can do without this. You will also find that a tube cutter (as used by plumbers) will be good for making clean cuts on aluminium tubing. Apart from an antenna clamp (U-bolt and V-block bracket), no special hardware or fittings are required.

Making this antenna is quite straightforward. If you have all the materials available you can probably do it in a couple of afternoons.

Fig.1 shows all the details of the 5-element antenna. It shows the dimensions of all the elements and the various hardware bits you will have to make to assemble the antenna. At the top is a plan view showing the length of all five elements and their spacing along the boom.

Screws & nuts

After a few years' exposure to the elements, many antennas are in a poor state. Aluminium may not "rust" but it does oxidise, particularly in seaside areas or in metropolitan areas where there is a lot of industrial fallout. Corrosion will also be a lot worse if you don't use the right screws and nuts.

We strongly recommend the use of stainless steel screws, nuts and washers throughout, whether for machine screws or self-tappers. They do cost a little more but they last indefinitely. You will find a good array of stainless steel screws available from ships' chandlers.

Don't, on any account, use brass screws. When used to attach aluminium elements these will corrode away almost before your eyes. Nor do we recommend galvanised, bright zinc or cadmium plated steel screws. In seaside areas these can be visibly corroded with just a few days' exposure.

In rural areas, away from the sea or city pollution, you can probably get away with galvanised screws but the antenna will last longer if you paint it.

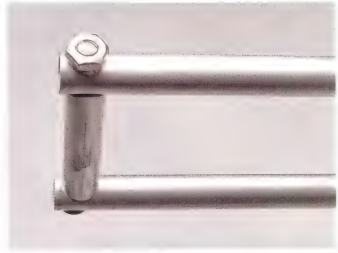
Starting work

Before you start, make sure you have obtained all the aluminium and hardware listed in the Bill of Materials. You will be frustrated if you get half-way through and find you can't progress further because you lack screws or some other item. Get 'em all before you start.

Cut the boom to length first. It is 2222mm long and made of 19mm square aluminium tubing, which makes drilling and assembly easier. If you are experienced in metalwork and have access to a set of V-blocks and a drill press, you could substitute 25mm diameter tubing for the boom. In fact, you could use 25mm stainless steel round tubing which is readily available from plumbing supply stores but it is expensive and not easy to work.

While you're at it, cut the folded dipole spacer which also uses the 19mm square tubing. It is 50mm long. You should have a piece of tubing about 120mm long left over as scrap. Don't throw it away. It will come in handy later. (When reassembling this prototype antenna after years in storage, we could not find the 50mm long spacer so we substituted two 19mm lengths of 19mm plastic conduit instead).

Note the two short sections of PVC conduit which act as spacers between the underside of the boom and the dipole insulator plate. Machine screws hold it all together. This is an alternative square tube spacer shown in Fig.1.



The ends of the folded dipole are fabricated using 42mm lengths of aluminium tubing shaped to mate with the upper and lower pieces. They are held together with 70mm long machine screws, nuts and split washers.

Now cut the 10mm diameter tubing for the director, three reflectors and parts for the dipole. Remember the old adage about "measure twice and cut once". It's hard to lengthen elements that are too short. Note that the three directors are all the same length, ie, 1270mm.

Next, centre-punch the boom for all holes prior to drilling. Note that the boom is 2222mm long and the total of the element spacings along the boom is 2182mm – see the plan diagram on Fig.1. Mark the hole centre position for the reflector element first, 20mm from one end of the boom, and then work your way along.

If you have a drill press which lets you drill all the element holes square through the boom you are fortunate. If not, mark the hole centre positions on both sides of the boom and drill from both sides. If you don't get the element holes lined up properly, you will have the elements skew-whiff.

A few words of advice on drilling is appropriate here. Drilling in thin wall aluminium tubing can be a problem and many people tend to end up with holes that are more triangular than round. The way around this problem is to drill all the large holes (ie, all 10mm holes) under size and then ream them out to the correct diameter using a tapered reamer.

Be careful when reaming holes out though because it is quite easy to get carried away and then end up with holes that are too big. Use a scrap piece of 10mm tubing to test when the holes specified at 10mm are the correct size.

Each director element and the reflector is held in the boom with a self-tapping screw, as shown in diagram A of Fig.1. Drill a 3mm hole at the centre point of each element but only through one side. Don't mount the elements on the boom yet though because the dipole should be assembled and mounted on the boom first.

Making the dipole

The folded dipole is made from five pieces of 10mm aluminium tubing, three long and two short. The detail of its assembly can be seen from the diagram at the bottom of Fig.1. The two short tubes, shown as diagram E on Fig.1, are cut and shaped using a file so that they key in with the top and bottom elements of the dipole. Further detail is shown in the accompanying photos.

The top and bottom pieces of the dipole are held at each end with a 70mm long 3/16-inch Whitworth or M4 screw, together with a nut and lock washer. At the centre, the lower halves of the dipole are terminated on an insulating plate (shown in diagram D of Fig.1). This plate is made of 3mm acrylic (Perspex or Lexan). The dipole halves are each secured to the insulating plate with a 19mm long 3/16-inch Whitworth or M4 screw, nut and lock-washer.

Terminals for the dipole are provided with two 32mm long 3/16-inch Whitworth or M4 screws, each fitted with

What Is A Yagi Antenna?

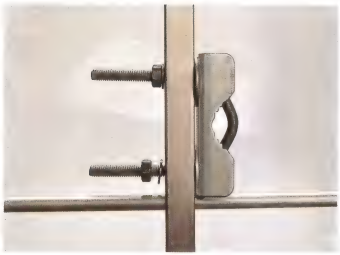
The Yagi antenna design was developed by H. Yagi and S. Uda at Tohoku Imperial University in Japan in 1926. In the VHF (very high frequency) bands, of which the FM band (88-108MHz) forms a small part, most antennas depend on electrically resonant elements, ie, elements which are a half-wavelength at the frequency of interest.

In its simplest form, the Yagi consists of a dipole element and an additional slightly longer parasitic element behind it, called the reflector. More complex designs have shorter parasitic elements in front of the dipole and these are called directors.

The reflector and directors are referred to as parasitic elements because they also resonate over a frequency range similar to that of the dipole. Part of the electromagnetic energy they capture is re-radiated and picked up by the dipole. Hence the director and reflectors add considerably to the signal which is picked up by the dipole on its own.

By suitably dimensioning the reflector and directors, it is possible to determine the overall frequency coverage of a Yagi antenna, its gain and its directional characteristics. In general, the more elements in a Yagi array, the higher will be its gain and the smaller the forward acceptance angle.

There is a law of diminishing returns though. Above a certain number of parasitic elements, no useful increase in gain is obtainable. There is a definite trade-off between the practical size of a Yagi and the amount of gain it provides.



We strongly recommend stainless steel (or at worst hot-dipped galvanised) fittings, as seen in this close-up shot of the U-bolt and V-block. You can find stainless fittings at automotive suppliers and ships' chandlers.

Do you have trouble drilling round holes? You'll do better by drilling the holes slightly undersize and then reaming them out to the exact size with a tapered reamer. Don't have a tapered reamer? Buy one – they're handy!

a nut and lock-washer plus a wing nut and flat washer.

The insulating plate is secured to and spaced off the main boom via a section of square tubing, shown as a "folded dipole spacer" in diagram F of Fig.1. The insulating plate is secured to the spacer with two 32mm long 8-gauge self-tapping screws which go through the spacer and into the boom. The top piece of the dipole is then secured to the boom with a 70mm long 3/16-inch Whitworth or M4 screw, nut and lock-washer

The details of the dipole insulating plate and fixing to the boom can be seen in the accompanying photos. Note that while we used white Perspex, you could use a piece of polycarbonate if that is what you have on hand. However, note our remarks on painting, later in this article.

By this time the antenna looks just about complete. You need to add the antenna clamp, to enable it to be attached to the mast and you will need a 300Ω-to-75Ω balun to match it to 75Ω coax cable.

You *could* use 300Ω ribbon if you wish (and also if you can get it!) and omit the balun but to obtain the most interference-free signal, we recommend coax cable for your installation. Also, 300Ω ribbon deteriorates in the weather a lot faster than coax.

Unfortunately, many antenna clamps are sold with a cadmium-plated and passivated finish. These have a "gold" finish. This is barely adequate for inland areas but rusts quickly in sea air.

We may seem to be paranoid about corrosion but since the SILICON CHIP editorial offices are only a kilometre or so from the seaside we are very aware of just how quickly metal hardware can rust and corrode.

If you can, buy U-bolts and clamps that are hot-dip galvanised or stainless steel, as used for car exhaust systems (or boat fittings), as these will last a lot longer. Be aware that zinc "plated" fittings are not as rust resistant as galvanised types. Zinc plated fittings have a smooth bright appearance while hot-dip galvanising is unmistakable – it has quite a rough appearance.

Whistling in the wind!

We also suggest that the ends of all the elements and the boom be stopped up with silicone sealant. This will stop them from whistling in the wind. Better still, you can buy Delrin plugs to suit the square aluminium tubing. These look neater.

It is also a good idea to paint your antenna, if you live in an area where corrosion is a problem. If nothing else, the dipole insulating plate should be painted as acrylic material does deteriorate in sunlight (ie, UV).

We suggest you leave the antenna for a month or so to weather it and then paint it with an etch primer. Finish it with an aluminium-loaded paint.

Installation

When you have finished your antenna you need to carefully consider its installation. There is no point in going to a lot of trouble making it if you don't install it properly.

Try to install your new antenna well away from existing TV antennas as these can have quite a serious effect on the performance.

Similarly, solar panels (photovoltaic or hot water), metal wall siding, nearby metal guttering, electric cabling, metal roofing or sarking (ie, reflective insulation such as Sisalation) can all have a bad effect on antenna performance.

And don't forget the effect of a hot water tank which may be lurking just beneath the roof tiles.

If you live on a busy street, try to install your antenna as far away as possible from the traffic side of your house. That will help minimise ignition noise from passing traffic.

Finally, install the antenna as high as possible above the roof and guttering. If that is a problem, try to install the antenna so that it is at least a half wavelength away from the nearest metallic object such as guttering or roofing. This means a distance of about 1.5 metres away from guttering.

Take care when installing the antenna. Safe working with ladders is particularly important. Take your time and don't take risks. You don't want to end up in hospital.

Line up the antenna so that it its directors (the shorter elements) are aimed at the main FM station(s) of interest. You may have to call the station to check where their transmitter is located because they are seldom at the same location as the studios.

The reflector and director elements are attached to the boom using self-tapping screws. Ideally, all screws, nuts and washers should be stainless steel to avoid corrosion. To check that screws are stainless, use a magnet.

A tube-cutting tool makes easy work of cutting the aluminium rods to length, with nice square cuts. They're also handy if you have to cut PVC conduit. And they're cheap, too (we bought ours at Bunnings for less than $20).

Unfortunately, the transmitters are often widely separated around the cities so you might have to compromise – aim at the one you most want or between them if there are two or more. But if you are really keen, you could consider installing a rotator, to obtain the very best reception from all stations.

You should find the stations come in loud and clear without too much fiddling around. If all you get is silence, or bad reception, check that your coax cable is connected properly and/or that it doesn't have a short somewhere (usually at the beginning or end).

Remember that coax cable is lossy so you want as short a length as you can install. And speaking of the coax, it should be firmly fixed to both the antenna boom and the mast. Otherwise it will flap around in the wind – annoying to start with but eventually leading to the coax failure.

Use either black cable ties (don't use white – they don't last) or black self-annealing insulation tape. SC

Because the impedance of the folded dipole antenna is 300Ω and the coax cable downlead is 75Ω, an inline balun (balanced-to-unbalanced transformer) must be used to connect the coax cable to the driven element. It is essential that this be made waterproof with either a matching boot (normally supplied with balun) or, failing that, some coaxial sealing tape. Note also how the coax is firmly attached to both the antenna boom and to the mast pipe to stop it flapping in the breeze.

Bill of Materials – 5 Element FM Antenna

Aluminium

2.3 metres of 19mm square aluminium tubing with 1.8mm wall thickness
8.5 metres of 10mm diameter aluminium tubing with 1mm wall thickness

Hardware

1 piece of white Perspex, Lexan, etc, 120 x 40 x 3mm
1 galvanised or stainless steel U-bolt and clamp to suit mast
4 8G x 13mm screws
2 8G x 32mm screws
3 3/16-inch Whitworth or M4 roundhead screws 70mm long
2 3/16-inch Whitworth or M4 roundhead screws 32mm long
2 3/16-inch Whitworth or M4 roundhead screws 19mm long
7 3/16-inch or 4mm ID split or lockwashers
7 3/16-inch Whitworth or M4 nuts
2 3/16-inch Whitworth or M4 wing nuts
2 3/16-inch or 4mm ID flat washers
Note: all screws, washers and nuts should be AS316-grade stainless steel

Miscellaneous

Mast and wall mounts or barge-board mount (hockey stick style),
300Ω to-75Ω in-line balun (Jaycar Cat LT-3028 plus matching boot and F-connector),
Appropriate length semi-air spaced coax cable (Jaycar WB-2004, WB-2006; Hills SSC32 or equivalent),
Plastic cable ties,
Silicone sealant.

Senator 10-inch Bass Reflex Loudspeakers

Part II

Last month we presented the Senator 10-inch bass reflex loudspeaker system and gave the details of its cabinet construction, based on a Bunnings Caboodle kit. This month we conclude the description with details of the crossover network PCB and enclosure wiring.

By Leo Simpson

Before discussing the cross-over network PCB, we should respond to a number of reader comments on last month's article. One reader noted that the prototype enclosure evidently had a circular hole in the baffle for the horn tweeter whereas the cabinet diagrams showed a rectangular cutout.

It is certainly true that the prototype cabinets did have circular tweeter mounting holes but we judged that this removed too much of the timber behind the horn and that it would be better and easier to make rectangular cutouts instead, ie, 140mm wide by 100mm high. After all, the more surface area in the baffle in the region behind the tweeter, the greater will be its rigidity and it will also lead to a better seal for the tweeter mounting.

Still on the subject of speaker mounting, it is desirable to provide a seal of draft-exclusion tape around the periphery of the woofer's chassis. This was shown in the rear photograph of the woofer on page 35 of the September 2015 issue.

Another reader commented that both side panels of the finished Kaboodle cabinets jut out by 8mm in relation to the top, front and back panels. He would prefer to have the side panels line up flush by reducing the width of all the panels associated with the Kaboodle 450mm Wall Cabinet kit. That would require the 300mm carcase width to be reduced by 16mm to 284mm. To do this you would need a bench saw which cuts perfectly square.

Now the side panels of the prototype enclosures do jut out and this was done to simplify construction and minimise the need to cut any of the finished Kaboodle panels. As it stands, only the top finished panel needs to be cut.

This means that the assembly procedure is more straightforward and also, in the opinion of all who have seen the finished cabinets, "in the wood" they look very good.

However, if you prefer, you could reduce the enclosed volume of the Kaboodle carcase (or if building cabinets from scratch) as suggested, and this should have little effect on the overall performance.

There were further queries from a reader concerning how the frequency response was measured and how the system power rating of 250W was determined. We put the first question to the designer, Allan Linton-Smith. He used an average of six near-field sweeps with two Bruel & Kjaer 4134 calibrated microphones with two Bruel & Kjaer 4669 preamplifiers feeding into an HP/Agilent35670a Audio

Analyser (with UK4 mic option power supply) and then into an Audio Precision System 2222 analyser.

We will come to the power handling of the tweeter later in this article.

We have also been informed by the local agent for Celestion loudspeaker, Electric Factory Pty Ltd, (www.elfa.com.au) that they only have limited supplies of the specified Celestion NTR10-2520D 10-inch woofer as it has been discontinued by the English manufacturer.

Fortunately, there is a suitable replacement, very close in specifications, the model NTR10-2520E and this has been extensively tested by Allan Linton-Smith so we can recommend it for the Senators. The chassis is exactly the same but there is a slight difference in the cone profile.

You will need one of these crossovers for each Senator speaker box. The jumper set (bottom right) is for adjusting the profile – its use is explained in the text.

Crossover network PCB

The crossover network used in the Senators is virtually identical to that in the Majestic loudspeaker system featured in the June 2014 issue, with only a slight component value change in the tweeter attenuator resistors. The modified circuit is shown in Fig.1.

The crossover uses a low-pass filter, comprising a sole 2.7mH air-cored inductor, to drive the woofer and roll off the signal at a rate about 6dB/octave above 2kHz. Similarly, the tweeter is fed by a high-pass filter, mainly involving a 4.7µF capacitor (C1) to roll off frequencies below 2kHz.

There is also an optional treble boost circuit which can be switched in and out to compensate for tweeter roll-off at high frequencies. After extensive listening tests, our preference was to leave the boost circuit in permanently and so we did not install the switches on the rear of the enclosures.

The crossover network also needs to match the efficiencies of the tweeter and the woofer, so that the overall frequency response is as flat as possible. As in the Majestic loudspeaker system, the horn-loaded tweeter is extremely efficient, at around 109dB/W@1m, far more efficient than the 10-inch Celestion woofer which is itself 95dB/W@1m – and this is a very efficient driver.

You might think that we could attenuate the signal to the tweeter using a single resistor. For example, by connecting an 8Ω resistor in series with an 8-ohm driver to halve the voltage level and thus provide 6dB of attenuation. However, this would also increase the source impedance "seen" by the driver by 8Ω (from the very low figure provided by the power amplifier) and performance would be significantly impacted due to poor damping.

Instead, we are using a divider with a low resistance, including two paralleled 3.3Ω 5W resistors across the tweeter, to keep its effective source impedance low. The horn tweeter is therefore better damped to keep distortion low. The parallel combination of the two 3.3Ω resistors and the tweeter is fed by two paralleled 12Ω 10W resistors.

This resistive divider provides more precise attenuation as it swamps the effect of the tweeter's impedance which rises with increasing frequency. The overall attenuation provided by this resistor divider is -14.6dB (assuming a tweeter impedance of 8Ω) and this matches the sensitivity of the tweeter to the woofer.

As a consequence of this amount of signal attenuation, the power dissipation in this resistive divider is a significant issue. In effect, we are throwing away about 66% of the power which would otherwise be fed to the tweeter!

With that in mind, some readers may question the relatively modest power rating of the resistors we have specified. At a peak program power of 250W, that seems like a lot of power to be dissipated! But there are a couple of reasons why we can manage the situation with much lower-rated resistors.

Even when driving the speaker system at a peak of 250W, the average program level will typically be only a small fraction of this; perhaps around 10W, at most. Secondly, a good deal of that program power will be going to the woofer.

With a typical recording, the energy in each octave is about half that of the octave below. So even though we using resistors with a total power rating of 30W, for home (hifi) use, these should be more than adequate.

Construction

Fig.2 shows the PCB layout. Start with the spade lugs; we used the PCB-mounting type however chassis-mounting spade lugs can also be pressed into service. For the PCB-mount type, there are various ways they can be fitted as there are four holes per position but we aligned them with the board edges and placed them as close to the edge as possible.

Solder them in place with a high-power iron. Start with the pins on the bottom side but it's also a good idea to ensure that there are solder fillets from the top side pad to the sides of the spade connectors too.

If using chassis-mounting spade lugs, use either the single-lug type or cut off one lug from a double-lug connector. Install each one by first feeding an M4 x 6mm machine screw up through the hole in the bottom of the board, then fit a shake-proof washer, then the connector, then another shake-proof washer and finally the nut. Tighten the nut with the lug projecting

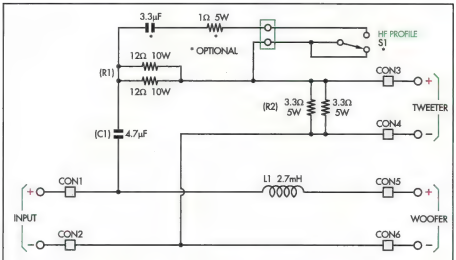


Fig.1: the crossover circuit is quite simple, consisting primarily of inductor L1 to act as a low-pass filter for the woofer and a 4.7µF capacitor as the high-pass filter for the tweeter. Resistor pairs R1 and R2 attenuate the tweeter signal so that its output level is matched to the woofer. The remaining components form a switchable treble boost circuit.

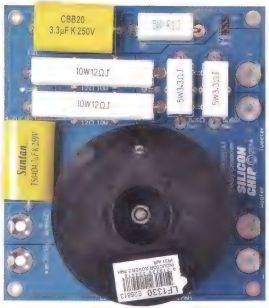
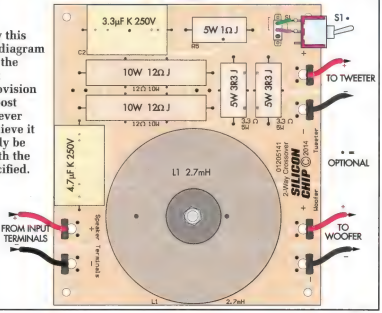


Fig.2: follow this PCB layout diagram to assemble the crossover. It includes provision for treble boost via S1; however we don't believe it will normally be required with the tweeter specified.



out from the edge of the PCB.

The capacitor(s) go in next. Bend the leads to fit the pads and push them down so they sit flat on the PCB before soldering them in place. Note that we have provided multiple pads in case you prefer to use radial types (eg, X2-style polypropylene capacitors).

Polyester capacitors are not ideal as they are less linear but would probably work OK. The 4.7µF capacitor next to next L1 must be fitted. The other is optional depending on whether you want the treble boost feature. Solder the capacitor leads on both sides of the board, assuming you're using the specified axial capacitors.

We've provided pads so that the wirewound resistors can be supported by sections of stiff tinned copper wire, so that if they are exposed to shock or vibration, their primary solder joints are not the only means of support. You don't have to fit these support "trusses"; they are optional.

The wirewound resistors should be spaced off the PCB by a few millimetres, to help power dissipation. That's done by pushing each resistor down onto a 2 or 3mm-thick spacer. You then turn the PCB over and solder the leads, on both sides of the PCB. The 1Ω resistor can be pushed all the way down onto the PCB if desired, as it handles relatively little power.

The next step is to fit a pin header to connect S1, if you are using it. Once it's in, install inductor L1.

The inductors used in our prototypes came from Jaycar (Cat LF-1330) but these have been discontinued as a stock line and are presently being run out at a discount price. Get yours while you can. We hope to arrange for an alternative source for these inductors or we will provide instructions on how to make your own bobbins and wind the inductors, in a future issue.

The leads of the inductor should have the enamel coating scraped off its two ends; while they are supplied pre-tinned, the tinned sections are too far from the bobbin to allow it to be soldered to the PCB. You will have to scrape them back to the point where they exit from the bobbin, then tin those sections.

Mount the inductor using a Nylon, brass or stainless steel M4 machine screw and nut. It is most important that you do not use a steel screw and nut because that would increase the inductance quite substantially as well

as making it a non-linear component. Then solder and trim the leads.

Mounting the crossover PCB

While the crossover PCBs in the prototype Senators were installed behind the internal sloping panel inside the cabinet, we do not recommend this position as it would be virtually impossible to remove the PCB if a fault subsequently developed.

Instead, we recommend mounting the crossover PCB in front of the sloping panel, on the floor of the cabinet, using four self-tapping screws. To connect the PCB, you need to crimp 6.3mm yellow female spade connectors onto the ends of the wires from the woofer and tweeter and plug these into the appropriate connectors on the PCB.

We also need some 400mm-long spade-lug to spade-lug cables using spare speaker wire off-cuts to connect the input terminals on the PCB to the binding posts mounted on the rear panel of the speaker.

If using the treble peaking switch, drill a hole through the rear panel and wire the switch up across one of the pairs of terminals marked on the PCB (ie, the middle pin and one of the upper pins). Alternatively, use a jumper shunt instead, shorting out the indicated pins to enable the treble peaking or placing it across the lower pins to disable peaking.

Finishing off

Your Senator speaker box(es) are now complete and almost ready for use.

However, we do not recommend using them "flat on the floor" as this will tend to make the bass "boomy". Raising them by, say, 100mm or so will virtually eliminate this problem and as a bonus, will raise the tweeters up to a level which is more in line with a typical listening position.

Fortunately, Bunnings have an ideal solution to the problem, again intended for kitchen cabinets. We bought sets of their "leggz" 100mm cabinet furniture legs, as seen below.

Each pack contains four legs so is suitable for one speaker box. Once fitted, they have the added advantage of being height-adjustable so can help fix any minor discrepancies in floor levels.

You simply screw the legs to the outer corners of your speakers, in (say) 100mm from the sides and front.

Sit back, relax with your favourite music . . . and enjoy! SC

Bunnings' "leggz" are intended for furniture use so are ideal for the Senator speakers.

Parts List – Senator Crossover

(one required per speaker box)

1 PCB, code 01205141, 107 x 120mm (available from www.siliconchip.com.au/shop)
1 2.7mH air-cored inductor; (Jaycar LF1330; see text)
1 M4 x 10mm machine screw and nut (Nylon, brass or stainless steel)
6 PCB-mount 6.3mm spade connectors, 5mm pitch (Altronics H2094) (CON1-CON6) OR
6 chassis-mount 6.3mm spade lugs plus M4 machine screws, shake-proof washers and nuts
1 3-pin header, 2.54mm pitch (CON7)*
1 jumper shunt*
1 SPST or SPDT toggle switch*
1 2-way cable terminated with female header plug*
4 No.4 x 12mm self-tapping wood screws
* optional component for treble peaking network – see text

Capacitors

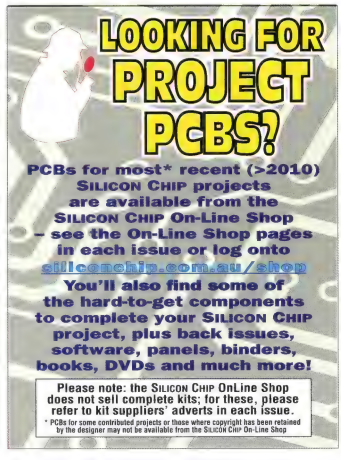
1 4.7µF polypropylene capacitor (Jaycar RY6954)
1 3.3µF polypropylene capacitor (Jaycar RY6953) (optional, for treble boost)

Resistors

2 12Ω 10W 5% 2 3.3Ω 5W 5% 1 1Ω* 5W 5%

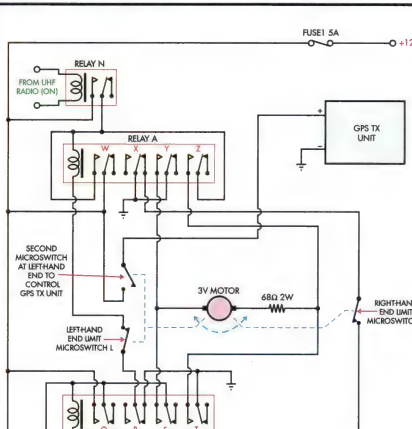
Additional Parts For Speaker Connections

1 pair long binding posts, red & black (Altronics P2004/P2005)
8 yellow 6.3mm female crimp spade "quick" connectors (Jaycar PT4707, Altronics H1842)
1 2m length heavy duty figure-8 speaker cable (eg, Jaycar WB1732, Altronics W2130)



CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



UHF-switched GPS guidance system

This system was devised to remotely switch on and off a GPS tractor guidance transmitter situated on a hilltop that's about 2km from the shed where the tractor is kept. The original concept was to use UHF telemetry equipment for the radio link but the remote site only has small solar panel and battery which could not run a UHF radio receiver that draws as much as 200mA just on standby, as well as the GPS transmitter.

The solution involved using a 151MHz transmitter/receiver pair that is specified to work up to 5km. Its receiver draws as little as 35mA idle current at 12V DC.

The transmitter/receiver link is used to switch the power to the GPS unit using a 3V hobbyist motor and gear set which opens or closes microswitches to control power to the GPS transmitter. It works as follows.

Initially, let's say that the motor shaft is at the righthand end and the GPS transmitter is off, as its control microswitch is open. At the same time, the lefthand limit switch is closed while the righthand limit switch is open. Thus, when the UHF receiver's "on" output (relay N) closes, current can flow from the 12V supply through relay A's coil, through the lefthand limit switch and to ground.

Relay A turns on and its W pole latches it in this state. Simultaneously, the X pole disconnects relay B's coil from ground so both relays can not be energised simultaneously. While relay A is on, 12V power and ground are connected to the motor through poles Z and Y respectively, turning the motor until the lever reaches the lefthand limit switch. This switch then opens, de-energising the relay coil and thus powering the motor down. At this point, the lever will have also activated the GPS transmitter microswitch, powering the transmitter up.

The same process happens in reverse when the UHF receiver gets an "off" signal, triggering relay F which latches relay B on until the lever reaches the righthand limit switch, at which point the transmitter will have turned off. The functions of relay B poles Q, R, S & T correspond to those of relay A poles W, X, Y & Z except that relay B drives the motor in the opposite direction by reversing its supply polarity.

Each time the unit is activated, the motor runs for about three seconds before it's turned off by one of the limit switches activating. Because both relays and the motor are off most of the time, the only current drawn on standby is the 35mA for the UHF receiver.

Peter Howarth,
Gunnedah, NSW.

Editor's note: while this is a novel and interesting way to solve the problem, a simpler solution would be to drive a dual-coil latching relay (eg, Jaycar SY4060) from the UHF receiver outputs and use one set of the relay's contacts to switch power to the GPS transmitter unit.

Having said that, this circuit could be useful in applications where the motion of the motor is the primary purpose, eg, as a gate controller or to open or close a door or window.

Peter Howarth is this month's winner of a $150 gift voucher fro Maxx & Forbes

24-pattern LED chaser display

This chaser circuit is built around Atmel's ATmega8, a low-power CMOS 8-bit microcontroller programmed to display 24 patterns of dancing LEDs at Port B. The internal frequency of the micro is set to 1MHz.

Once the circuit is switched on, all eight LEDs blink twice before the first pattern is initiated. In Pattern 1, two LEDs are turned on at a time, shifting from the middle towards the sides.

In Pattern 2, one LED lights up on each side and is shifted towards the middle. Pattern 3 is initialised by switching on four LEDs in the middle and turning on the remaining LEDs one by one towards the left and right sides.

In Pattern 4, two LEDs are on on each side first. Then the remaining LEDs light up one by one. Patterns 5 and 6 are similar to Patterns 3 and 4 but at the initial stage, six LEDs are on.

Pattern 7 begins by turning on a LED on the right side and shifting it to the left side. Pattern 8 is the opposite of Pattern 7. In this case, the LED is shifted to the right.

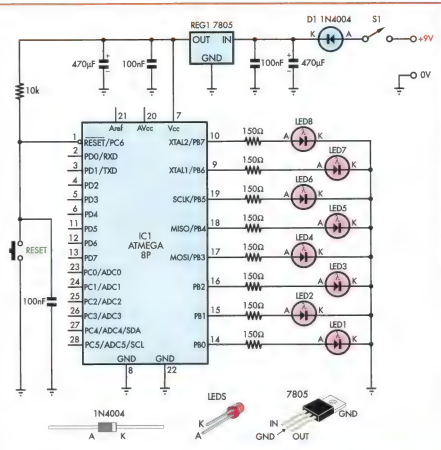
Patterns 9-20 are similar to Patterns 7 and 8 but with an increasing number of moving dots which are shifted to the righthand or lefthand side.

For instance, in Patterns 19 and 20, seven LEDs are shifted to the left and right side of Port B.

In Patterns 21 and 22, all the LEDs are initially switched on and then turned off one by one on the left and right sides. In Pattern 23, one LED is first turned on from the right side and then the other LEDs are turned on until the left-most LED is turned on.

Pattern 24 is the opposite of Pattern 23: the LEDs light up one by one from left to right until the right-most LED is switched on.

Mahmood Alimohammadi, Tehran, Iran. ($45)



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PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13) 10A 230V Motor Speed Controller (Feb14)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11), Quizzical (Oct11) Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13), Nicad/NiMH Burp Charger (Mar14) Remote Mains Timer (Nov14), Driveway Monitor Transmitter (July15)
PIC16LF88-I/P	Garbage Reminder (Jan13), Beiibird (Dec13)
PIC16LF88-I/SO	LED Ladybird (Apr11)
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10) Semtest (Feb-May12)
PIC18F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)
PIC18F45K80	USB Power Monitor (Dec12)
PIC18F4550-I/P	GPS Car Computer (Jan10), GPS Boat Computer (Oct10)
PIC18F14K50	USB MIDIMate (Oct11)
PIC18F27J53-I/SP	USB Data Logger (Dec10-Feb11)
PIC18LF14K22	Digital Spirit Level (Aug11), G-Force Meter (Nov11)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12), Touchscreen Audio Recorder (Jun/Jul 14)
PIC32MX170F256B-50I/SP	Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor*
PIC32MX170F256D-I/SP	Low Frequency Distortion Analyser (Apr15) Bad Vibes (June 15)
PIC32MX170F256D-50I?/T	44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost)
PIC32MX250F128B-I/SP	GPS Tracker (Nov13) Micromite ASCII Video Terminal (Jul14)
PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14), Digital Effects Unit (Oct14)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Level (Sep11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
dsPIC33FJ64MC802-E/P	Induction Motor Speed Controller (revised) (Aug13)
dsPIC33FJ128GP306-I/PT	CLASSIC DAC (Feb-May 13)
ATTiny861	VVA Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)
ATTiny2313	Remote-Controlled Timer (Aug10)

When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

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CURRAWONG AMPLIFIER Hard-to-get parts pack: *(Dec 14)* **$50.00**
LM1084IT-ADJ, KCS5603D, 3 x STX0560, 5 x blue 3mm LEDs, 5 x 39µF 400V low profile capacitors

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NOTE: The listings below are for the PCB only – *not a full kit.* If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
USB BREAKOUT BOX	JUNE 2011	04106111	$10.00
ULTRA-LD MK3 200W AMP MODULE	JULY 2011	01107111	$25.00
PORTABLE LIGHTNING DETECTOR	JULY 2011	04107111	$20.00
RUDDER INDICATOR FOR POWER BOATS (4 PCBs)	JULY 2011	20107111-4	$80 per set
VOX	JULY 2011	01207111	$20.00
ELECTRONIC STETHOSCOPE	AUG 2011	01108111	$10.00
DIGITAL SPIRIT LEVEL/INCLINOMETER	AUG 2011	04108111	$10.00
ULTRASONIC WATER TANK METER	SEP 2011	04109111	$10.00
ULTRA-LD MK3 AMPLIFIER UPGRADE	SEP 2011	01209111	$5.00
ULTRA-LD MK3 AMPLIFIER POWER SUPPLY	SEP 2011	01109111	$15.00
HIFI STEREO HEADPHONE AMPLIFIER	SEP 2011	01309111	$30.00
GPS FREQUENCY REFERENCE (IMPROVED)	SEP 2011	04103073	$30.00
HEARING LOOP RECEIVER/NECK COUPLER	SEP 2011	01209101	$10.00
DIGITAL LIGHTING CONTROLLER LED SLAVE	OCT 2011	04110111	$10.00
USB MIDIMATE	OCT 2011	23110111	$25.00
QUIZZICAL QUIZ GAME	OCT 2011	08110111	$25.00
ULTRA-LD MK3 PREAMP & REMOTE VOL CONTROL	NOV 2011	01111111	$30.00
ULTRA-LD MK3 INPUT SWITCHING MODULE	NOV 2011	01111112	$20.00
ULTRA-LD MK3 SWITCH MODULE	NOV 2011	01111113	$10.00
ZENER DIODE TESTER	NOV 2011	04111111	$20.00
MINIMAXIMITE	NOV 2011	07111111	$10.00
ADJUSTABLE REGULATED POWER SUPPLY	DEC 2011	18112111	$5.00
DIGITAL AUDIO DELAY	DEC 2011	01121111	$25.00
DIGITAL AUDIO DELAY Front & Rear Panels	DEC 2011	01121112/3	$20 per set
AM RADIO	JAN 2012	06101121	$10.00
STEREO AUDIO COMPRESSOR	JAN 2012	01201121	$30.00
STEREO AUDIO COMPRESSOR FRONT & REAR PANELS	JAN 2012	01201121P1/2	$20.00
3-INPUT AUDIO SELECTOR (SET OF 2 BOARDS)	JAN 2012	01101121/2	$30 per set
CRYSTAL DAC	FEB 2012	01102121	$20.00
SWITCHING REGULATOR	FEB 2012	18102121	$5.00
SEMTEST LOWER BOARD	MAR 2012	04103121	$40.00
SEMTEST UPPER BOARD	MAR 2012	04103122	$40.00
SEMTEST FRONT PANEL	MAR 2012	04103123	$75.00
INTERFACEMATRIX-ONE	MAR 2012	08102121	$10.00
12/24V 3-STAGE MPPT SOLAR CHARGER REV.A	MAR 2012	14102112	$20.00
SOFT START SUPPRESSOR	APR 2012	10104121	$10.00
RESISTANCE DECADE BOX	APR 2012	04104121	$20.00
RESISTANCE DECADE BOX PANEL/LID	APR 2012	04104122	$20.00
1.5kW INDUCTION MOTOR SPEED CONT. (New V2 PCB)	APR (DEC) 2012	10105122	$35.00
HIGH TEMPERATURE THERMOMETER MAIN PCB	MAY 2012	21105121	$30.00
HIGH TEMPERATURE THERMOMETER Front & Rear Panels	MAY 2012	21105122/3	$20 per set
MIX-IT! 4 CHANNEL MIXER	JUNE 2012	01106121	$20.00
PIC/AVR PROGRAMMING ADAPTOR BOARD	JUNE 2012	24105121	$30.00
CRAZY CRICKET/FREAKY FROG	JUNE 2012	08106121	$10.00
CAPACITANCE DECADE BOX	JULY 2012	04106121	$20.00
CAPACITANCE DECADE BOX PANEL/LID	JULY 2012	04106122	$20.00
WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$20.00
WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD	JULY 2012	05106122	$10.00
SOFT STARTER FOR POWER TOOLS	JULY 2012	10107121	$10.00
DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	04108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	08108121	$10.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	09109121	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110122	$20 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
USB POWER MONITOR	DEC 2012	04109121	$30.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00

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REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp (Sept'11))	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAMP 4-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
LiTi Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A/230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NiMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID MAIN SUPPLY	JUNE 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04104142	$15.00
VALVE SOUND SIMULATOR PCB	AUG 2014	01106141	$15.00
VALVE SOUND SIMULATOR FRONT PANEL (BLUE)	AUG 2014	01106142	$10.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-TACHOMETER MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THERMOMETER PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
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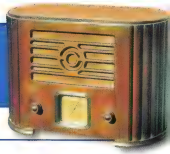
Vintage Radio

By Associate Professor Graham Parslow



AWA 1946 Fisk Radiola Model 92 Egg Crate

Despite having modest performance and cut-price circuitry, many vintage radios have become collectors' items due to their distinctive cabinet styles. The AWA Fisk Radiola Model 92 "egg crate" radio from 1946 is one such set.

MANY ICONIC radios from the golden age of radio have been given nicknames by collectors due to their appearance. These radio nicknames include "scales", "beehive" and the "plum pudding". In the case of the AWA Model 92 radio, its "egg crate" nickname was derived from the distinctive style of its speaker grille.

Often, the same cabinet style was used for a number of different circuits, so dating this egg crate radio isn't easy. I discovered this when my curiosity was aroused about the date of a photo that was on the July 2015 cover of the HRSA journal "Radio Waves". It was of a J. P. Aarons store in Melbourne and showed an egg crate radio in the window.

After some discussion with Kevin Poulter who had acquired the image, a date of 1946 emerged as the most probable for the "Radio Waves" photo. The egg crate cabinet definitely existed in 1939 but it may well have been released earlier.

The dial on the radio featured in this article is clearly labelled "The Fisk Radiola" and this is also shown in the Model 92 advertisement reproduced with this article. However, Ernest Fisk left AWA in 1944 and this ended "The Fisk" series of radios, the exception being the Model 92 that continued with his name. By contrast, other post-war models that were housed in the egg crate cabinet bear only the title "Radiola", which was proprietary to AWA and RCA America.

The hyperbole of the AWA advertisement for the Model 92 really is over the top for what I have long-considered to be an ugly duckling. Part of the promotion reads: "The strikingly beautiful cabinet, designed by an artist of distinction, has exquisitely graceful lines and is a masterpiece of streamlined simplicity". However, despite my initial reservations, I became much more favourably inclined to this unique package as the restoration proceeded.

That said, when you cast an eye over the minimalist circuit used in the Model 92, AWA's claim that it was "Australia's finest broadcast receiver" was ludicrous.

As can be seen from the photos, there were just two controls on the front of the cabinet (one on either side of the dial) and these were for volume and tone. The tone switch has only two positions: treble-cut on and treble-cut off. The tuning control is situated on the righthand side of the cabinet.

Circuit details

The Model 92 circuit appears in AORSM (Australian Official Radio Service Manual) Volume 4, which covers 1940-41 radio receivers. It is a 4-valve superhet and uses common valves from the late 1930s.

Fig.1 shows the circuit details as they appeared in the AORSM manual. It's rather unconventional in appearance because the valves are shown "upside down", with the plates to-

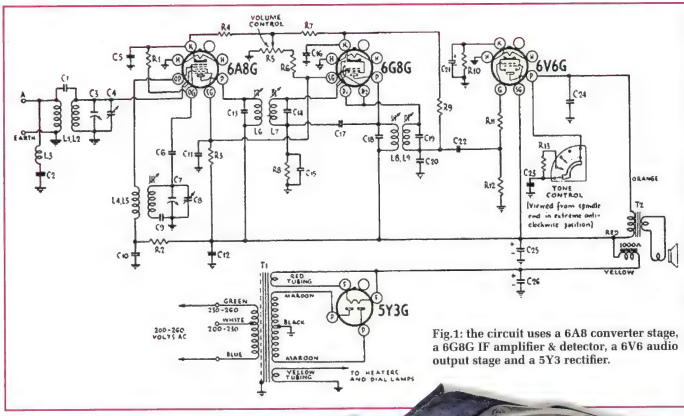


Fig.1: the circuit uses a 6A8 converter stage, a 6G8G IF amplifier & detector, a 6V6 audio output stage and a 5Y3 rectifier.

wards the bottom and the heaters at top.

As shown, a 6A8 mixer oscillator stage is followed by a 6G8 which functions as an IF amplifier and detector (there's no AGC). A single 6V6 pentode is used as the audio output stage, while the rectifier is a 5Y3 which has its heater powered from a separate 5V power transformer winding.

Interestingly, the speaker is an electrodynamic type and its 1kΩ field coil also filters the HT rail from the rectifier. It's very much a pre-war design, although the ARTS&P label on the featured radio indicates that this particular radio was manufactured post-war, ie, in 1946. This date is also consistent with the plastic figure-8 twin-core flex that was used for the 240VAC power lead.

Cleaning up

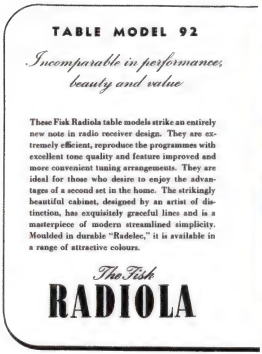
This radio had waited on a shelf for over five years before the "Radio Waves" cover finally motivated me to restore it. Its initial appearance was quite untidy, due mainly to a torn speaker grille cloth (styled with coarse mesh fabric), a loose dial window, dirty knobs and a faded Bakelite cabinet.

Internally, the radio was covered in grime and that meant that the chassis would have to be thoroughly cleaned before I could work on the circuit.

This view shows the chassis before it was cleaned. It was covered in dust and grime but was otherwise in good condition.

I tackled the cabinet first. The original speaker grille fabric was beyond repair and that presented a problem because its coarse pattern is part of the character of this radio. Fortunately, I soon discovered that I had some similar fabric on hand, the only problem being that it was pale blue. That problem was quickly solved by spraying the fabric with ivory-coloured paint, a technique that works quite well.

Next, the knobs were removed and cleaned using a brush and warm, soapy water. I then cleaned the cabinet and wiped it over with "Armor All" and it came up looking almost like new.



AWA's claim that the Fisk Radiola Model 92 was "Australia's finest broadcast receiver" was a bit over the top, considering the modest circuit it employed.

Once the outside was looking good, the chassis was brushed out to remove any fluff and then liberated from its grime using a turpentine wash. It was then blown out with compressed air to thoroughly dry it.

That done, the broken dial cord was removed and replaced. I also discovered that the 5-inch speaker cone had a small tear and this was repaired using PVA glue.

Electrical restoration

The original fly leads to the top-cap grids of the 6A8 and 6G8 valve were sheathed in cotton-covered rubber insulation. Over the years, this covering had frayed and now looked tatty. As a result, the corroded grid caps at the ends of these leads were removed and cleaned so that they would later make good connections to the valve grids. The valve-cap wiring was then sleeved with yellow heatshrink tubing, both for appearance and to ensure good insulation, and the valve caps reattached.

Next, the two dial globes were removed and checked. Blown dial globes are a common problem in old radios but these both tested OK, so they were simply cleaned and reinstalled in their positions behind the colourful dial glass.

Under the chassis

At first glance, the under-chassis wiring and parts were all original except for the electrolytic capacitor (25μF 25V) used as a cathode bypass on the 6V6 output pentode.

A close inspection indicated that the two chassis-mounted HT filter electrolytics (C25 & C26) had dried out, with perished red rubber at the base of the cans. Rather than remove them, these capacitors were left in place on the chassis in order to maintain the original appearance. It was just a matter of cutting the appropriate leads to disconnect them and then installing two 33μF 450V electrolytics under the chassis to serve as the HT filters.

In addition, paper capacitor C22 (0.05μF), which couples the detected signal from the 6G8 to the 6V6 audio output stage, was replaced with a 0.047μF 630V Mylar unit. Based on long experience, I always replace this usually leaky capacitor as a matter of routine. This prevents leaked HT from overloading the output pentode with positive grid bias, which can quickly destroy both the output valve and the output transformer.

The identical 0.05μF tone control capacitor was also replaced as a matter of course.

The last modification before switch-on was to remove the old 2-core mains flex and install a 3-core cable. This allowed the chassis to be securely earthed, making the unit much safer to work on. In addition, the new cable was securely clamped into position. The original cable had been secured by tying a knot in the lead just inside the chassis (see photo), which is illegal these days. It was common practice back then, though.

Applying power

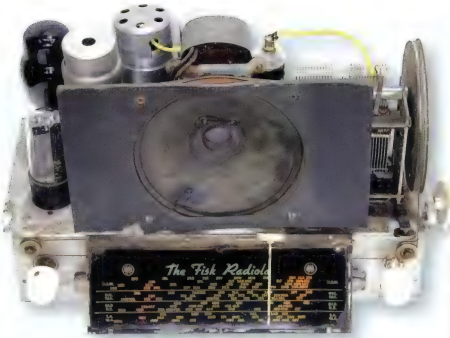
Power was first applied with all the valves removed. This resulted in glowing dial globes and a steady power consumption of about 10W (as expected), so I was optimistic that the set would work as soon as the valves were installed. Unfortunately, my optimism was misplaced, as I quickly found out.

To test the set, I reinstalled the valves, set the volume control to about one third, applied power and allowed time for the valves to warm up. The power consumption settled down to 56W (AWA quote 60W) but not a sound could be heard.

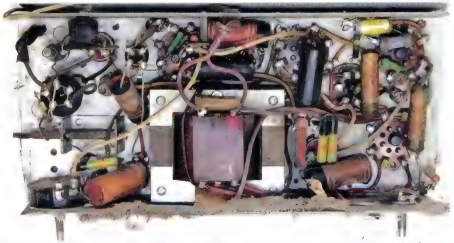
Tuning across the dial gave no result but when I turned the volume up to full, the set gave a sudden "crackle" and multiple stations became audible. It sounded rather like a poor crystal set.

I again tuned the set across the dial and the result was much the same, although the mix of stations did change.

The cabinet came up looking like new but the torn speaker cloth had yet to be replaced when this photo was taken. It was later swapped out for a similar coarse-weave fabric that had been sprayed with ivory-coloured paint to match the original colour.



This is the fully restored chassis, ready for re-installation into its cabinet. In addition to the electrical repairs, the dial cord required restringing and a small tear in the speaker cone was repaired with PVA glue.



This view shows the underside of the chassis prior to restoration. Note the knot (now illegal) tied in the twin-flex mains cord that was originally fitted to the set. The volume control and several faulty electrolytic and paper capacitors had to be replaced to restore the set to operation, along with various other repairs.

That indicated a fault somewhere in the mixer-oscillator circuitry.

Checking under the chassis did not reveal any problems so I moved on to the above-chassis components. It didn't take long to spot the problem – the lead to one section of the tuning capacitor had come adrift. This was quickly resoldered and the radio could then be correctly tuned to individual stations.

However, that wasn't the end of the set's problems because the sound could only be heard when the volume control was close to its maximum setting. Below this setting, there was complete silence (no hiss at all) and this indicated that either the oscillator or the IF amplifier wasn't working. This seemed weird until a look at the circuit diagram revealed that the volume control was in an unusual location.

In this circuit, the volume control (R5) is a 4kΩ wirewound pot. It was easily disassembled by removing the backplate and a quick check with a multimeter located an open circuit in the middle of the resistance wire. As a result, a replacement pot was substituted with the expectation that this would fix the problem but it made no difference. Even with the good pot in place, the radio still had only two modes of operation – either complete

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The ARTS&P label on the back of the chassis indicates that this Model 92 set was manufactured in 1946. It's in quite good condition considering its age.

silence or overload at high volume.

It was time to take a closer look at the circuit. As shown on Fig.1, the wire-wound volume pot varies the voltage at the cathodes of both the 6A8 mixer-oscillator and the 6G8 IF amplifier. As a result, the pot varies the negative bias on the control grid of each valve and thus varies its amplification. What's more, because this gain control works partly in the RF section, it explains the lack of AGC.

Modifying the volume control

Unlike other volume control circuits, this arrangement means that the set's volume increases as the wiper moves towards earth. In other words, the volume increases as the grids become less negatively biased by the voltage developed across the cathode resistance. This meant that even with an open circuit in the middle of the original pot's winding, the high volume end still worked because the wiper was still connected to earth via the intact section.

The problem was that this radio had a critical cut-off bias that prevented the front-end from working at low volume settings. As a result, I decided to modify the circuit and install a more conventional volume control circuit.

After some experimentation, I ended up permanently installing a 100Ω resistor in place of the wirewound pot. This gave a sufficient reduction in front-end gain to avoid overload on strong local stations while still preserving enough gain for weaker stations. A conventional volume control was then installed by replacing R12 (500kΩ) in the grid circuit of the 6V6 output stage with a pot and connecting C22 to its wiper.

One surprise discovery was the existence of a 25μF electrolytic capacitor between the original volume pot's wiper and earth. This capacitor isn't shown on the circuit diagram (but is in the parts list) and was apparently installed as a cathode bypass. As a result, a new 22μF capacitor was paralleled with the fixed 100Ω bias resistor I'd installed in place of the pot.

The end result was a reasonably standard performance from the radio. However, I got one more surprise when I checked the voltages around the 6V6 output pentode. Its plate was at 247V, the screen at 272V and the grid bias, as set by the cathode resistor, was -14.3V. This bias is too high for a 6V6 to give undistorted amplification; instead, it normally needs -7V to -9V.

Despite this, the audio was quite clean. So why wasn't there any evident distortion?

One possible answer was that the valve fitted to the set wasn't really a 6V6. Unfortunately though, this valve had no identifying markings on it, even though I had been careful not to rub any markings off the valves during the cleaning process.

As it turned out, an experienced member of the HRSA knew the answer. AWA immediately post-war may have substituted a 6F6 for the 6V6, since the 6F6 was sometimes more readily available. It's also possible that a repair technician with a spare 6F6 made the substitution at a later time. However, the clincher that this radio has a 6F6 is that its cathode resistor (R10) has a value of 325Ω, not 250Ω as specified in the parts list for a 6V6.

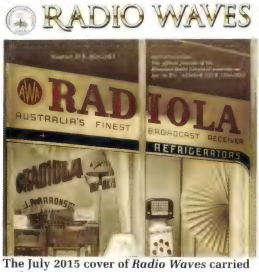
The higher-value resistor generates the higher bias required for a 6F6, so that explains the mystery.

More egg crates

There is more to the egg crate story than the Model 92 because AWA also housed the R84, R86 509M and 174 models in this cabinet. A publicity release from AWA dated December 1939 states that the new Radiola Model 174 is "housed in a strikingly beautiful cabinet of moulded Radelec available in a variety of attractive colours." Those colours were ebony, walnut, jade, blue, pink and ivory. This model also featured a loop aerial that "obviates the need for both aerial and earth connections for local reception".

In summary, the egg crate radios might be electrically unremarkable but their distinctive style and variant colours make them collectable. Provided they are obtained in reasonable condition, they are generally easy to work on and repair.

Footnote: a special thank you to HRSA President Mike Osborne for reviewing this article. His suggestion of adding AGC, as in the AWA model 500MY, will be a future project. SC



The July 2015 cover of *Radio Waves* carried a photo of a J. P. Aarons radio store in Melbourne. Note the Model 92 egg crate radio in the window display.

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Tolerance of output current sharing resistors

I have a simple technical question on the Balanced Attenuator (SC May 15). The 10Ω output resistors on IC2a etc are specified on the drawing as 0.1% and in the parts list as 1%. As they are not included in your difficult to obtain pack, I presume that they are 1%. It is my first attempt of a significant SMD project, so I am on a practical learning curve. (K. J., via email).

● The 10Ω output resistors are not critical; they merely ensure equal output current sharing across the paralleled op amps. A 1% tolerance is quite adequate.

Driveway Monitor detection query

What distance away from a vehicle will the Driveway Monitor (SILICON CHIP, July 2015) reliably detect its presence? I will be building this device as it seems to address so many problems living in a rural setting, with wallabies and kangaroos and other wildlife using the driveway. It is about 200 metres long, with a metal cattle grid at the entrance. (J. B., via email).

● It detects vehicles up to about 2m from the driveway; that is, from the monitor to the closest side of the vehicle. It is mainly intended for a driveway where the vehicle is restricted to being within a certain range.

You would be best in a rural situation to position the Monitor where the vehicle has to come within range, such as between two posts. That could probably be on a post that's part of the fence that runs up to the cattle grid.

We are not sure what effect the steel cattle grid would have on the Monitor. If it is magnetised it may send the monitor's sensor off range. So that would just mean having a guide fence a little further away from the cattle grid and the monitor mounted on that.

Supercap for Garbage Reminder

In the Ask SILICON CHIP pages of the August 2105 issue, a reader wrote about the Garbage Reminder losing its configuration when the battery is changed. As the proud owner of one myself, could this not be avoided with a supercap across the 3V rail? I guess that it might have to be charged first, otherwise the rail will take a dive. (D. H., via email).

● You are right, a supercap could easily be used to take over supplying the current during the cell changeover. A 47 millifarad (47mF) super capacitor would suffice.

Frequency switch link confusion

I am about to start putting the Frequency Activated Switch kit (SILICON CHIP, June 2007) together and have just read the instructions and found something I don't understand. On page 5 of the kit instructions, it talks about LK1 and D3 and points out that the photo shows the switching on falling frequency with LK1 in L/H and D3 in the top position and orientation of L/H.

I want the switch to operate on rising frequency, ie, switch on at 80 km/h and above and then switch off at 74km/h. The configuration in the photograph is what I think I need but as I am inexperienced, I wanted to check that I am looking at it correctly. (G. B., via email).

● For your application, LK1 goes in the L/H position and diode D3 is positioned as shown on the Fig.1 overlay (not the photo) with its anode (A) to the left. The striped end of the diode (ie, the cathode [K]) goes to the right on the PCB.

Transformer For Playmaster 60-60 Amplifier

I was wondering if you might be able to help. I need to replace the transformer in the Playmaster 60/60 stereo amplifier (*Electronics Australia*, May-July 1986) I built in the 1980s. Somehow, I put a screw through the windings and wrecked it.

The 160VA toroidal transformer was 35-0-35V and 15-0-15V and was a custom-made unit I think. It no longer appears in the Altronics catalog and I cannot find an equivalent online from any of the transformer suppliers.

If not available, could I use a toroidal with dual secondaries 35-0-35V 160 VA and the existing regulated power supply which uses 15V 7815/7915 regulators? I would imagine at the very least they would run hot or they may fail. And if I added power resistors in line they would radiate EMI I suspect.

I know the amplifier is old but it still works beautifully and I don't really want to build a replacement unless I have to, in which case the 20/20W Class-A Amplifier might be the one. (G. M., via email).

● Any transformer replacement for the the Playmaster 60-60 amplifier must fit in a very limited space. The simplest and easiest approach is to replace it with a 30V-0V-30V toroid from Altronics, Cat. MC5330. In theory, the maximum power output will be reduced by about 25% to about 45W per channel but any audible difference in performance will probably be very slight. Note that the MC5330 transformer also has 15-0-15V windings, so the 15V regulators will be no more stressed than before.

The alternative is to get a transformer wound by Harbuch Electronics (www.harbuch.com.au) or another transformer manufacturer.

No Ballast Required For High-Energy Ignition System

I am about to construct the High Energy Ignition System (SILICON CHIP, November & December 2012) to drive a Holden type coil, as used in the Jacob's Ladder (SILICON CHIP, February 2013), and I am wondering whether the coil would need a ballast resistor?

The earlier Jacob's Ladder kit (SILICON CHIP, April 2007) that used a Darlington transistor had a 0.47Ω resistor in series with the coil primary. Was this to limit current for the coil's sake or the transistor's?

The latest version with the IGBT does not have it. I am using the ignition kit as a stand-alone ignition system for model engines that I build.

Also, I wish to be able to switch between points and a Hall effect sensor and from what I can see I would need to be able to switch between R1 & R3 on the trigger input and set up some terminals on the case for the different wiring etc. I was thinking of a simple switch with the centre terminal as a common to the trigger input, and with R1 soldered to one end terminal and R3 to the other. Do you see any issues? (I. B., via email).

● You do not need a ballast resistor if you set the dwell correctly, so that the coil does not become saturated for a long period. That way, the coil will remain relatively cool.

You could switch between points and Hall Effect triggering with R1/R3 switching as you suggest. The only thing to be aware of is whether the Hall effect trigger output goes high (5V) at the point of firing. If the Hall effect output goes low at the point of firing, you would also have to switch the trigger sense selection.

Alternatively, the iron vane that rotates within the Hall effect assembly could be rotated to produce the correct firing sense; ie, change the vane to exit instead of enter the Hall effect assembly at the point of firing, or vice versa.

Updating the Courtesy Light Delay

I built the original Courtesy Lights Delay (SILICON CHIP, June 2004) but have since upgraded my courtesy lights to LEDs, so I built the updated unit from the October 2014 issue. However, the test 12V LED simply does not light at all. The voltage reading at pins 1 & 4 of IC1 are good at 5.02V.

I have built and operated many of your projects over the years but this one has me stumped. I have checked everything and all seems well. I would appreciate a little guidance here.

Is it possible the programming in IC1 could be corrupted? The PCB and IC were both supplied by you, of course. I don't have a logic probe (since I ran over the last one), so I may have to get a new one one. (P. S., via email).

● Check that pin 5 of IC1 goes high when the door switch is opened and is low when closed. Check that you get a 1MHz signal at pin 3 and that there is a nominal 12V DC between the gate and source of Q1 (using a multimeter) during the time-out period.

If there is no DC voltage, perhaps transformer T1's leads are not correctly soldered. Ensure that the insulation on the wires is scraped off where they solder to the PCB. Check that pin 2 is normally high at 5V unless the lights or ignition are on.

The IC may not be programmed correctly if there is no 1MHz signal at pin 3 during time out.

Subwoofer controller switching change

I have built the Subwoofer Controller from the August 2007 magazine using the Jaycar KC5442 kit. Having made changes to my set-up I would now like my Subwoofer Controller to be able to switch on two Studio 350 amplifiers which drive my subs.

My problem is that in the specifi-

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PIR Spotlight Needs Modification

I have purchased a PIR LED spotlight (Cat. SL-3232) from Jaycar and it almost does what I want. The turn-on duration is a maximum of 20s but I need to extend that to minutes to enable us to shower during power outages. I could also use one in our stairwell during an outage. Twenty seconds is fine as an emergency light for the bedroom as we can find the torch in that time.

I have tested it with multiple turn ons and heat does not seem to be a problem and battery size can easily be increased if needed. The PIR feature will remove the groping in the dark, for switches. I would use it in the daylight mode to come on any time it senses movement to confirm it is operational. (B. B., via email).

● The PIR LED spotlight would contain a simple timer that could possibly be modified if you could gain access inside the unit. It seems strange that the maximum time out is only 20s. Controls on the spotlight allow for PIR sensitivity and time out period adjustment. Make sure the time setting is rotated fully clockwise.

It may be possible to gain access to the timer to see what type of circuitry is used in order to extend the time period. Maybe just a capacitor needs to be increased in value. Without any more information, it is not possible to make a particular suggestion.

cations, it shows the solid-state relay as having a maximum current rating of 2A. I'm pretty sure that two Studio 350 amplifiers are going to potentially draw much more than 2A.

Can I use the SY-4050 relay rather than the SY-4089 with say, a small outboard PCB to accommodate connections? Or perhaps the SY-4084 Triac type could be used? Also, would it help using the Soft-Start kit from the July 2012 magazine, to extend the contact life of the relay when the initial current surge occurs at start up? (P. S., via email).

● A better approach might be to replace the SY-4089 relay with the SY-4084 Triac type relay, as its 40A current rating should mean that you won't need to worry about fitting a soft-start circuit as well.

SMD assembly was a challenge

I have just completed the V/I/R reference from this month and it works well (after I put the link in). I do not like soldering these tiny things and I wonder how are large TV and other devices made with these things? They are different shapes, lead spacings and are not easy to hold in place. What holds 1000 of them on the board while robot solderers do their thing?

Maybe you could publish an article on this but unfortunately I guess you have to go overseas to find any serious manufacturing now. (J. G., via email).

● Congratulations on your success. Presumably, the next SMD project you attempt will not be so daunting.

In automatic assembly, the SMDs are held on the PCB with solder paste and then the PCB is fed through a reflow oven to complete the soldering process.

In fact, a great deal of SMD assembly is done in Australia and there are quite a few companies assembling their own. You can see a a series of videos on the process on David Jones' EEVblog#264. Go to www.youtube.com/watch?v=pHNpayYhBvM

Smoke alarm door monitor modification

I have every copy of Silicon Chip magazine from the first in "as-new" condition up until I retired at the end of 2007 and returned from Australia to England. I recall reading about a project that used (from memory) a condenser microphone linked to a smoke alarm in such a way that if a door or window was opened, it caused a momentary change of air pressure in the room which was sensed by the microphone which in turn triggered the smoke alarm to sound by shorting out its test contacts.

I have searched your on-line site unsuccessfully and, in desperation, have decided to write to you to ask if you could simply tell me the year and month of the issue that contained that project. Now that I am retired, I have taken up electronics once again and would dearly love to build this project

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Published in Dec 2012

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Wow! 10Hz - >2.5GHz in two ranges; 1us - 999,999s with a 12-digit LED display. It's a world beater and it's the perfect addition to any serious hobbyist's bench – or the professional engineer, technician, in fact anyone who is into electronics! You'll find it one of the handiest pieces of test gear you could ever own and you can build it yourself.

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You'll find the construction details at http://siliconchip.com.au/project/2.5ghz

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CLASSIC

Published in Feb 2013

Make just about any DVD or even CD player sound better by using this high-performance Digital to Analog Converter! It has three TOSLINK inputs, three SP/DIF inputs, USB audio inputs, SD card playback capability and a built-in headphone amplifier.

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Provision For SMD & Through-Hole Components On PCBs

In some recent projects, the Balanced Attenuator in the May 2015 issue is a good example, there is a requirement to use high-precision resistors to get the best common mode rejection ratio (CMRR). Also, if you produced another magnetic cartridge preamplifier, it would be desirable to use 1% tolerance resistors and capacitors in the feedback network to obtain a very close adherence to the RIAA equalisation curve.

In both cases, it turns out that SMD components are much cheaper and possibly more readily available than through-hole parts of equivalent precision. So why not make provision for both component types on your PCBs? That way, constructors can choose whether to use SMD or through-hole parts and it would also give more flexibility for the kit suppliers. (D. X., via email).

● That idea certainly has some merit. We could make footprints for standard quarter/half-watt resistors and MKT/ceramic capacitors which incorporate 1206 SMD pads and use these where possible. However, there are some disadvantages.

First, it would make it difficult to print a component value within the footprint on the PCB screen print, even though we always provide this information on the overlay diagram anyway. An alternative would be to put a (smaller) value label next to the component where possible, as we tend to do with other component types.

It also would make it harder to run top-layer tracks between the component pads. It would be possible to fit one thin track between 1206 pads and multiple tracks could still be run between the through-hole pads on the bottom layer. So for all but the most packed PCB layouts, it could probably be done.

But it is also possible that providing for alternative components on PCBs could lead to confusion when people are assembling the PCBs – something we definitely want to avoid, if we can.

It is true that some people actually find it easier to fit SMD passive components rather than through-hole because they avoid the need to constantly flip the PCB over and the leads do not need to be trimmed. They are also cheaper than through-hole components, particularly capacitors.

Ultimately though, we are inclined to the view that where high performance and compact size is required, the SMD approach is the way to go. And as time goes on, through-hole components for our existing PCB designs will be harder to obtain and hence there is more chance of those projects using through-hole rather than surface-mount components becoming obsolete.

and your kind response will save me a lot of time unpacking and checking all those back copies to find it. (R. C., via email).

● We cannot find a reference to such a unit being used with a smoke alarm but the Door Minder project from the February 1988 issue has a door detector that's based on changes in air pressure. It uses an electret microphone.

On that circuit, IC1b's output can be connected to the base of an NPN transistor (BC337, BC547 etc) which has its emitter and collector connected to the smoke alarm's test switch.

Make sure the polarity is correct, with the collector to the more positive side of the test switch. The emitter needs to connect to the Door Minder circuit ground.

Dummy load box for audio amplifiers

I have been looking into dummy loads for testing audio amplifiers and found that you had an article on a unit back in August 1992. Is this an audio or RF dummy load box? (T. D., Christchurch, NZ).

● The load box described in the August 1992 issue of SILICON CHIP was designed for testing audio amplifiers. It used jug elements as the loads, arranged in four banks of 10 in parallel, or 40 in total. That means that the design is now obsolete unless you can track down cheap jug elements. They no longer seem to be available or are very expensive.

Modifying the 3V to 9V converter

I bought the 3V to 9V DC-DC Converter project kit that featured in March 2004 from Jaycar. It works fine. I intend buying another one and I want to increase it to 20V output. To do that, I just need to change the values of two resistors. The article gives the resistor values for 15V output but not for 20V.

There is an equation to help calculate the values but I'm having trouble understanding it. The equation is:
Vout = Vref(1 + R1 / / R2/R3)
R1, R2, R3 = the resistor values
Vref = the reference voltage that the IC chip requires (TL499A IC chip)
Vout = The output voltage

The part where I'm stuck is this operator " / / " . What does it mean and what does it do in this equation? Because in the article it states that:
Vout = 1.26V(1+ 33kΩ / / 220kΩ/4.7kΩ) = 8.95V

So how does this equation reach this answer? (J. D., via email).

● The mathematical symbol " / / " means "in parallel with". In this case, the 33kΩ resistor is in parallel with the 220kΩ resistor. The resulting resistance value R is calculated as:
R = 1 ÷ (1 ÷ R1 + 1 ÷ R2)

So in this example,
R = 1 ÷ (1 ÷ 220kΩ + 1 ÷ 33kΩ) and so
R = 28.696kΩ

We can then substitute this into the above formula and calculate Vout as follows:
(1) Vout = 1.26V(1 + 28.696kΩ ÷ 4.7kΩ)
(2) 28.696kΩ ÷ 4.7kΩ = 6.105
(3) 1 + 6.105 = 7.105
(4) 7.105 x 1.26V = 8.952V

Ultra-LD Mk.4 amplifier module

First, being a new subscriber, I would like to congratulate you on the quality of SILICON CHIP.

I have a question regarding the Ultra-LD Mk.4 currently being described. I was looking at the previous issues in which you published a complete Ultra-LD Mk.3 amplifier, with preamp, input selector and power supply cards. Are you proposing to describe a full Ultra-LD Mk.4 amplifier, with updated

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Ask SILICON CHIP

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preamp, input selector and power supply PCBs? Or do you plan to revamp only the amplifier module?

I am asking because I'd like to build the whole project so I was wondering if I could get the full Mk.3 kit from Altronics and replace the Mk.3 module with the Mk.4 PCB instead?(O. A., via email).

● At this stage we are only revising the power amplifier module and the loudspeaker protector (to be described next month). Both can be regarded as drop-in replacements for the respective modules in the complete Ultra-LD amplifier sold by Altronics.

The loudspeaker protector PCB will be more compact and have a few circuit tweaks, as well as a number of on-board LED indicators.

DC-DC voltage regulator required

I am trying to find information relating to building a DC-DC voltage regulator with the following requirements: input voltage is 5-70V DC unregulated, supplied from a solar panel array while the output voltage is to be either 12V or 24V DC regulated. Any assistance would be greatly appreciated. (G. S., via email).

● We published a 120W 12V (or 240W 24VDC) charger for batteries using a 12V or 24V solar panel in the February 2011 issue of SILICON CHIP and this was revised in March 2012. We haven't published a regulator with such an input voltage range and we wonder why

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Currawong Valve Amplifier Is Motor-Boating

I recently completed a Currawong Valve Amplifier (SILICON CHIP, October to December 2014). All appears to be well apart from the level of "motor-boating" noise which is easily audible.

I have attached a scope screen shot which shows the output of the left and right amplifier channels. As can be seen, there are positive and negative spikes superimposed on 2mV or so of 50Hz.

The stated signal-to-noise ratio is -70dB and what I'm seeing doesn't seem to be within that limit. The ripple on the HT appears to be as expected. Any suggestions please? (D. H., via email).

● We have not had any other reports of motor-boating; yours is the first. We would be inclined to suspect defective capacitors or associated poor soldering. Check the power supply, the feedback network and the 100µF bypass capacitors for the 6L6 valves. Also, check that you have the correct 47kΩ and 6.8kΩ decoupling resistors installed in the HT rails.

Ask SILICON CHIP

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a practical solar panel array would have such a wide range. Such a regulator would require a step-up and step-down circuit, one to step up from 5V to 12V or 24V and the other for reducing voltages above 12V or 24V. A major factor is how much current needs to be supplied from the regulator.

Problem with ultrasonic anti-fouling unit

I have purchased a kit for the Ultrasonic Anti-Fouling unit (SILICON CHIP, September & November 2010) and completed the assembly. When I connected the unit I got a brief red light and the fuse blew. I have run the test as stipulated in your article that came with the kit and have set a 5V output on the potentiometer but still nothing.

I am attaching the pictures I have from the top. Kindly note that the blue wire coming from the battery is positive and the brown the negative.

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Also the transformer arrived with a minor damage. The top left black plate was broken but we sealed it. (J. J., via email).

● From your pictures, the construction looks good on the top side. However, the transformer clip behind Mosfet Q1 is not actually holding the ferrite core in place and that might be the problem. The core seems to be fractured also on the side near the 2200µF capacitor. SC

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Next Issue

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